APRIL 1958

JOURNAL OF THE IRON AND STEEL INSTITUTE

4 GROSVENOR GARDENS · LONDON SWI

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VOL. 188 PART 4

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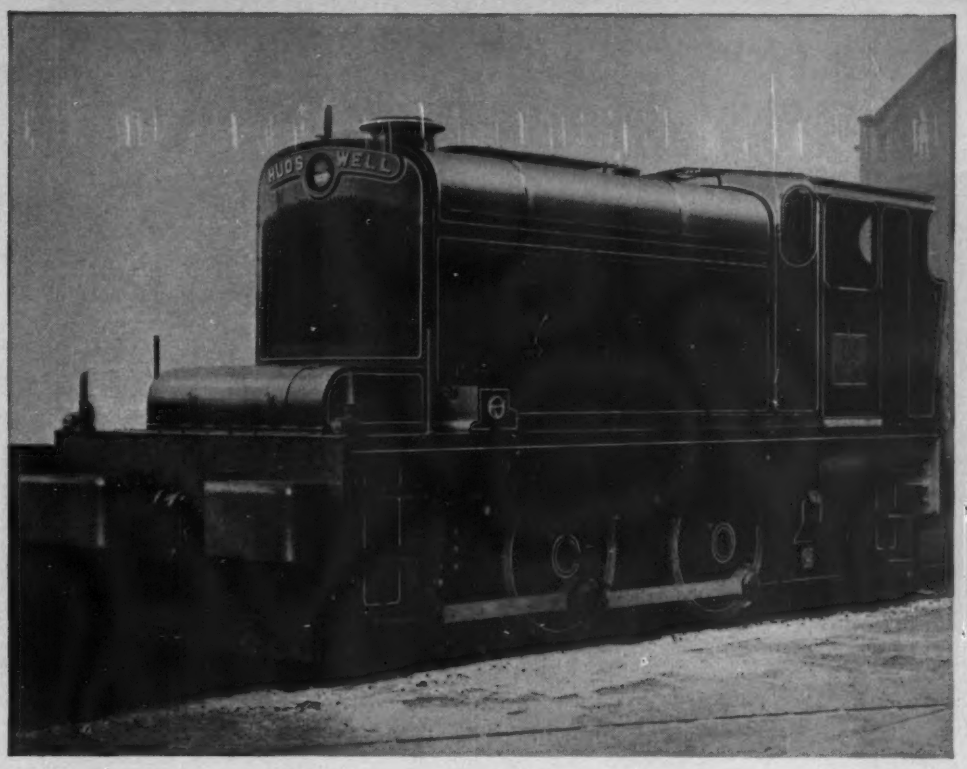

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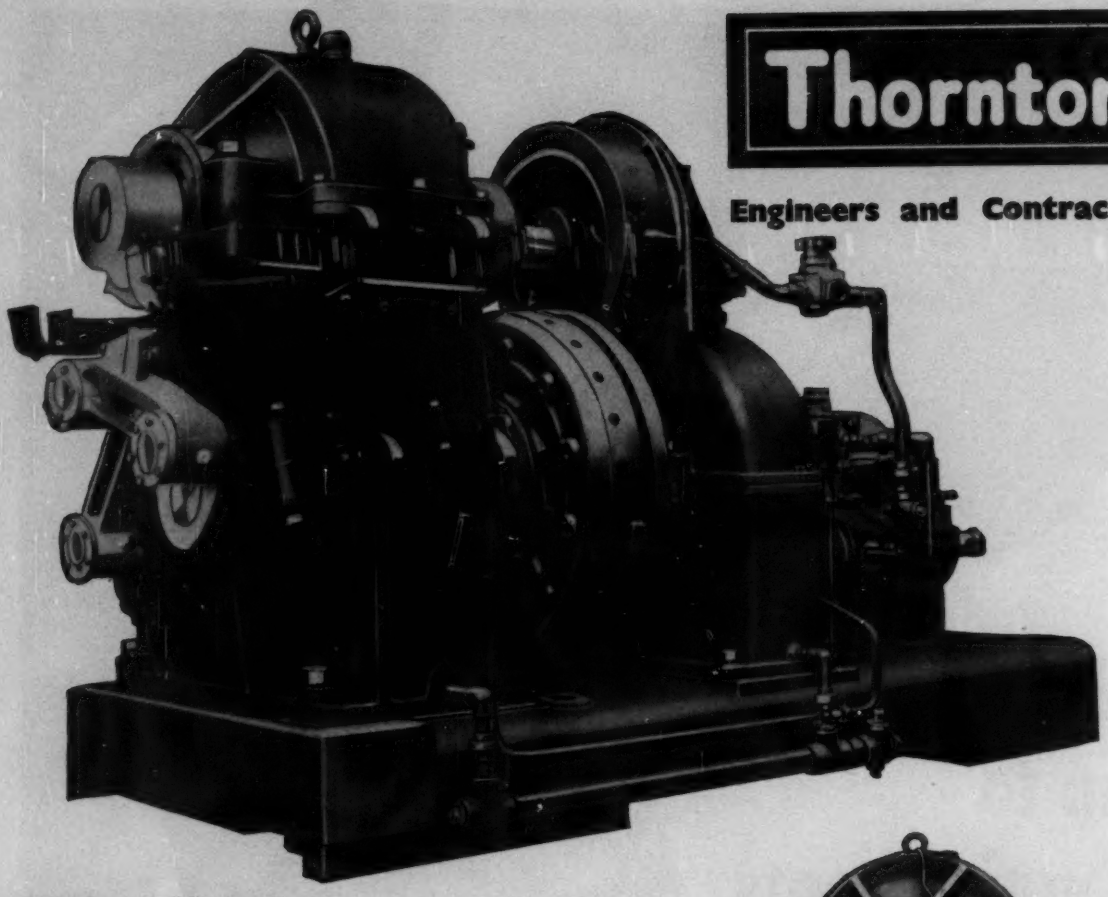

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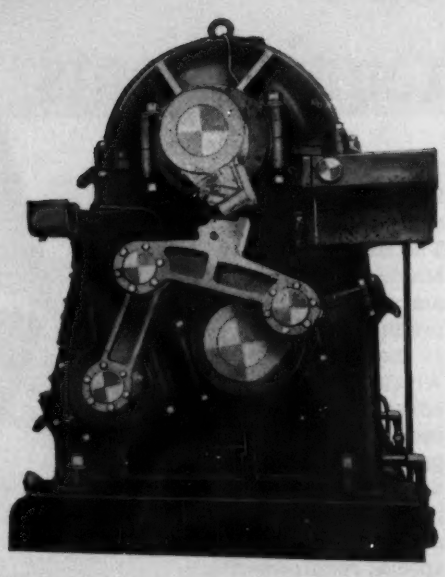

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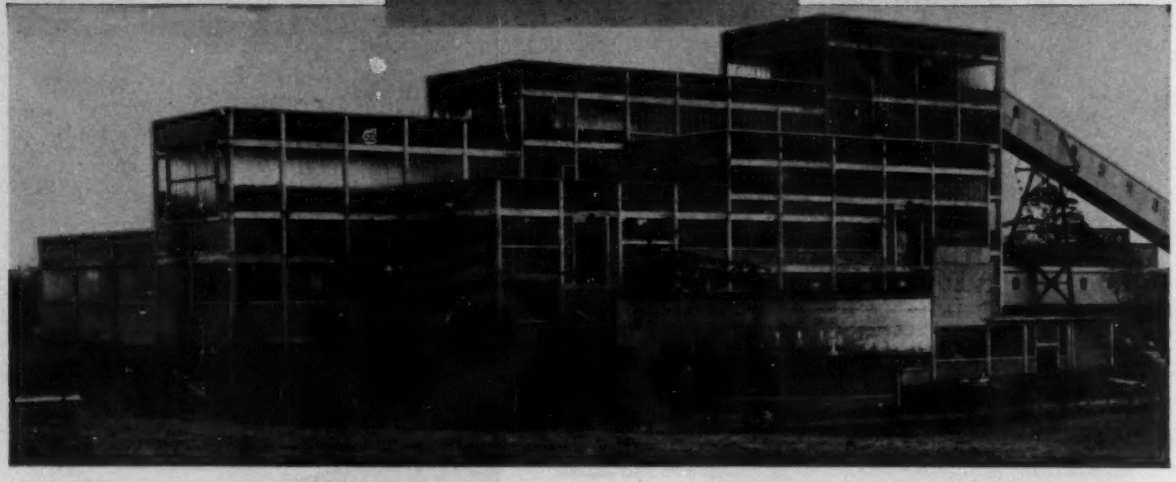

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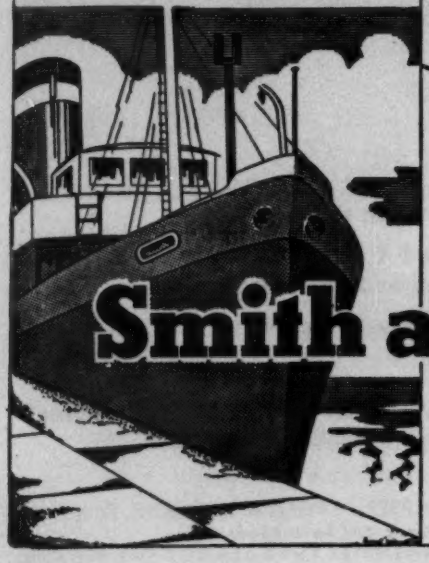

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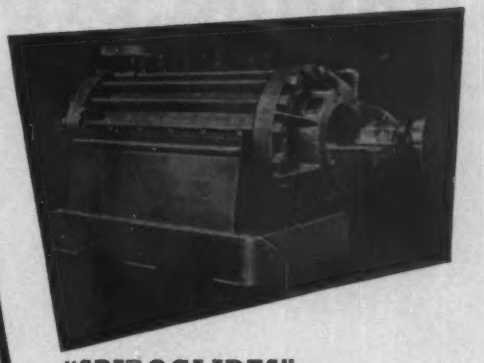

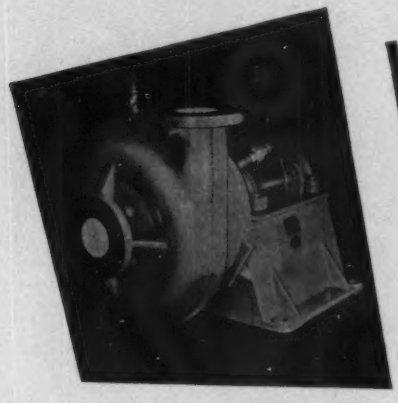

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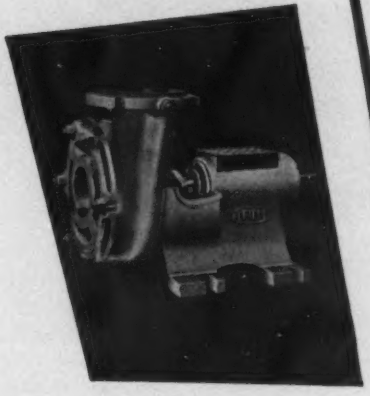

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P.502 "A"

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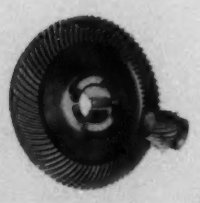

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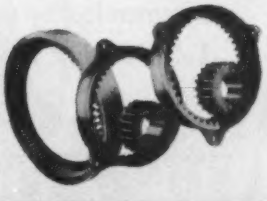

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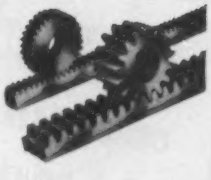

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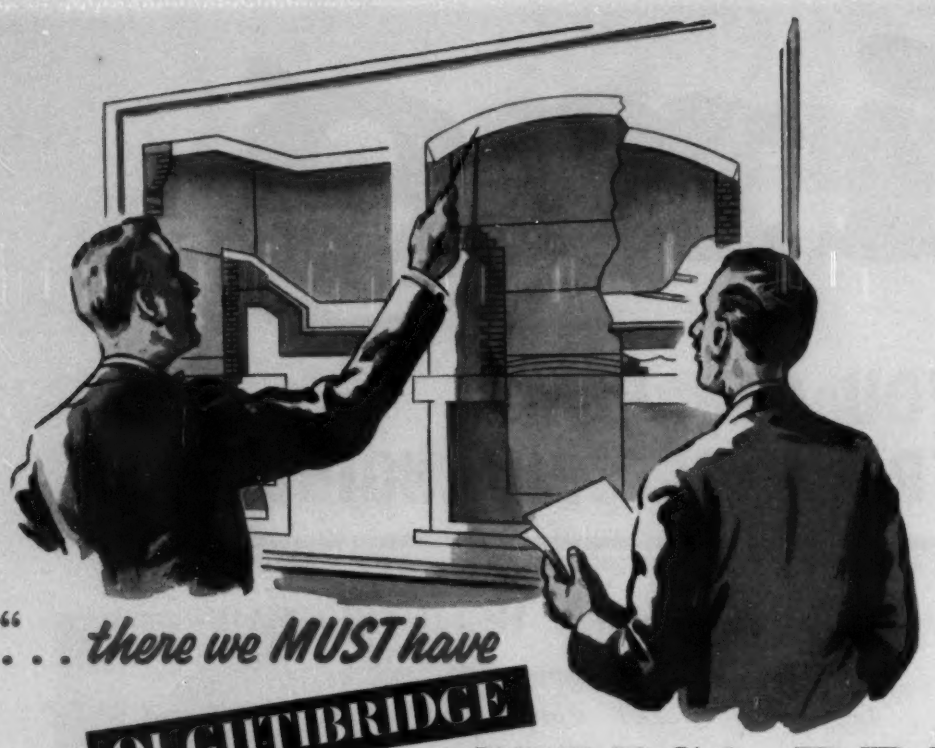

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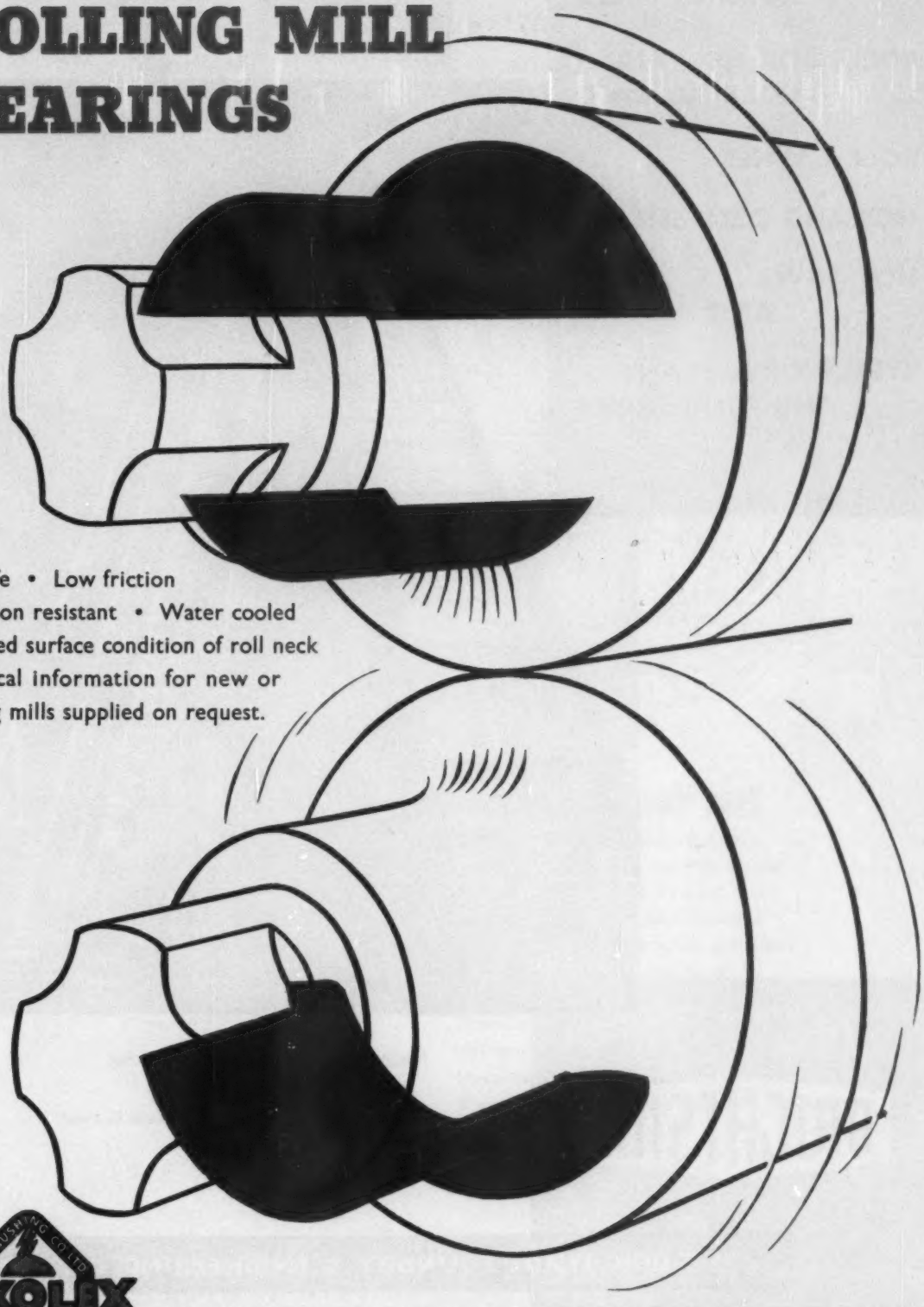

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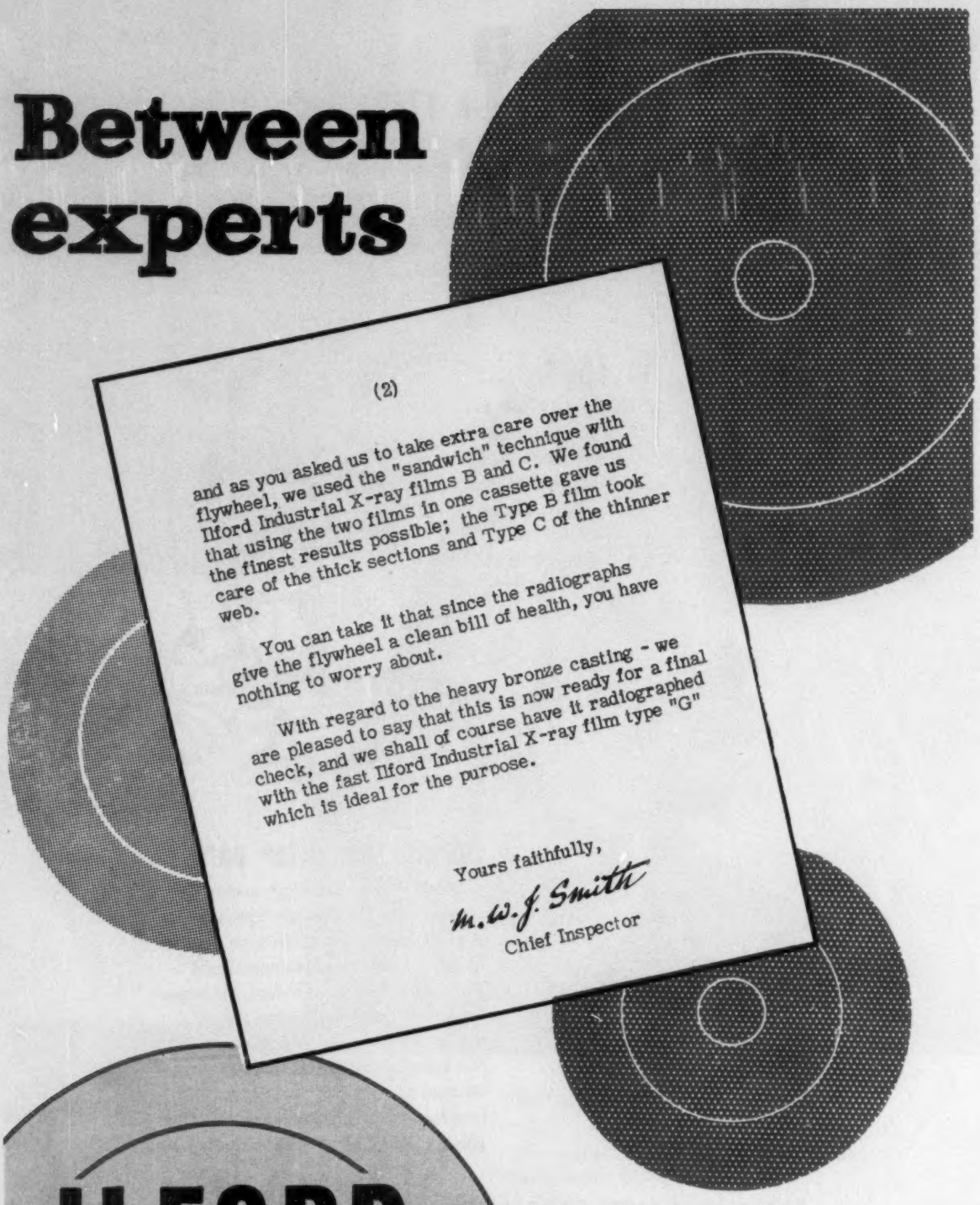

(2)

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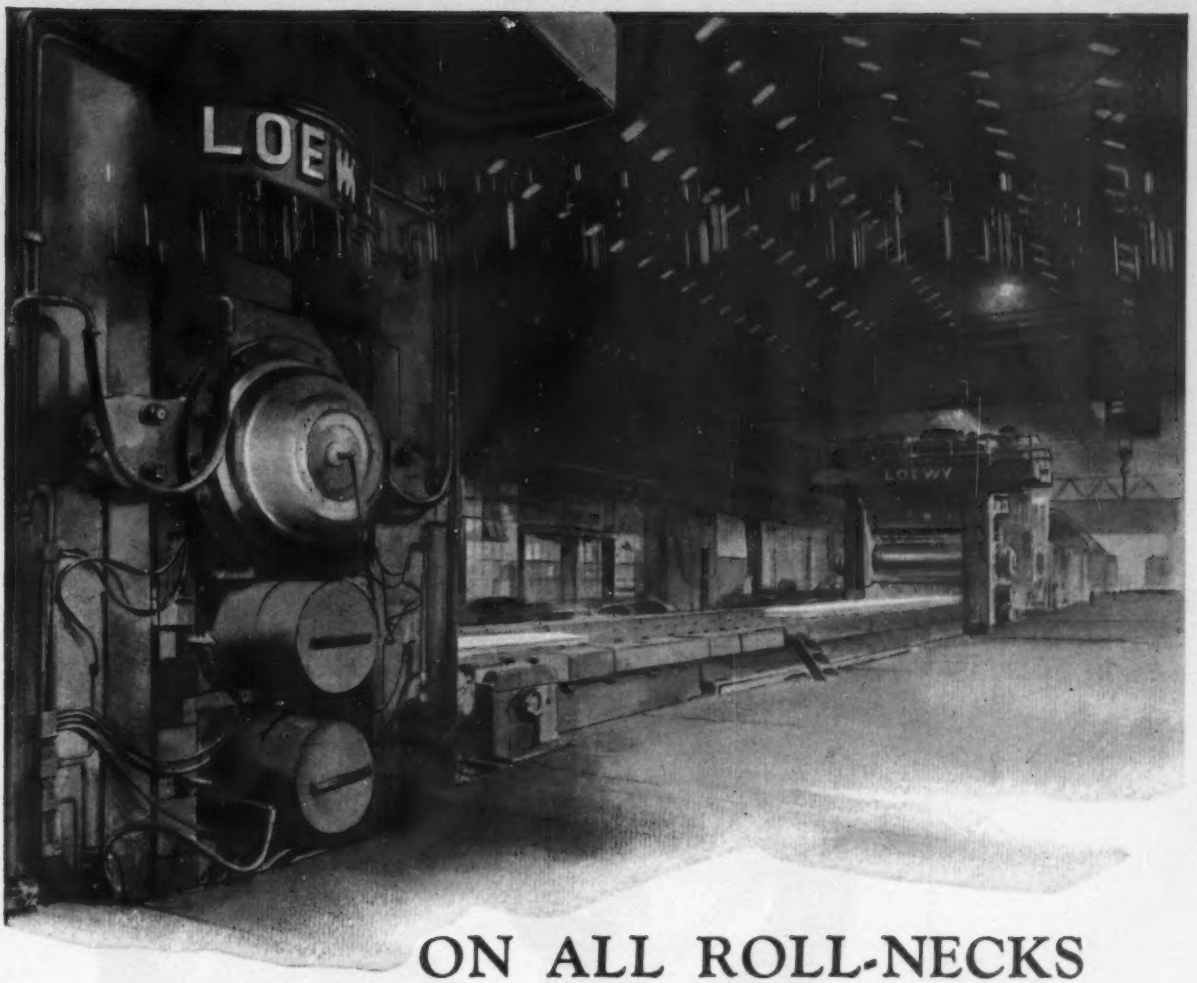

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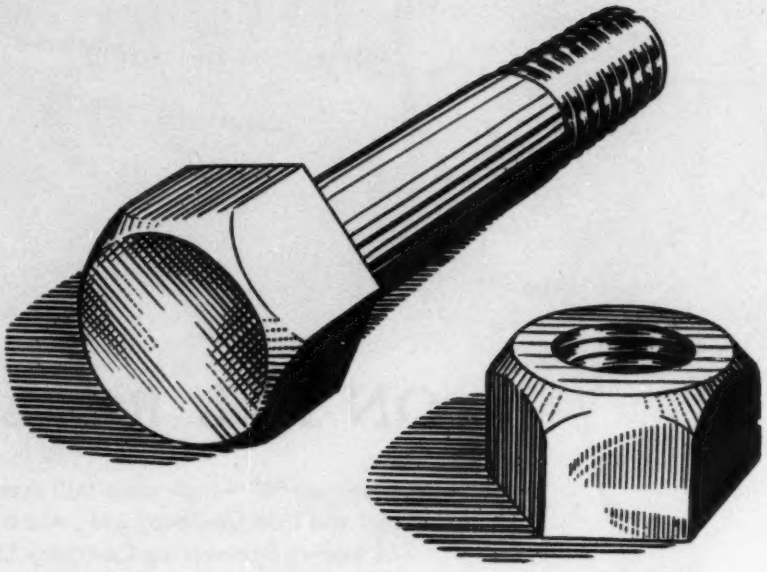

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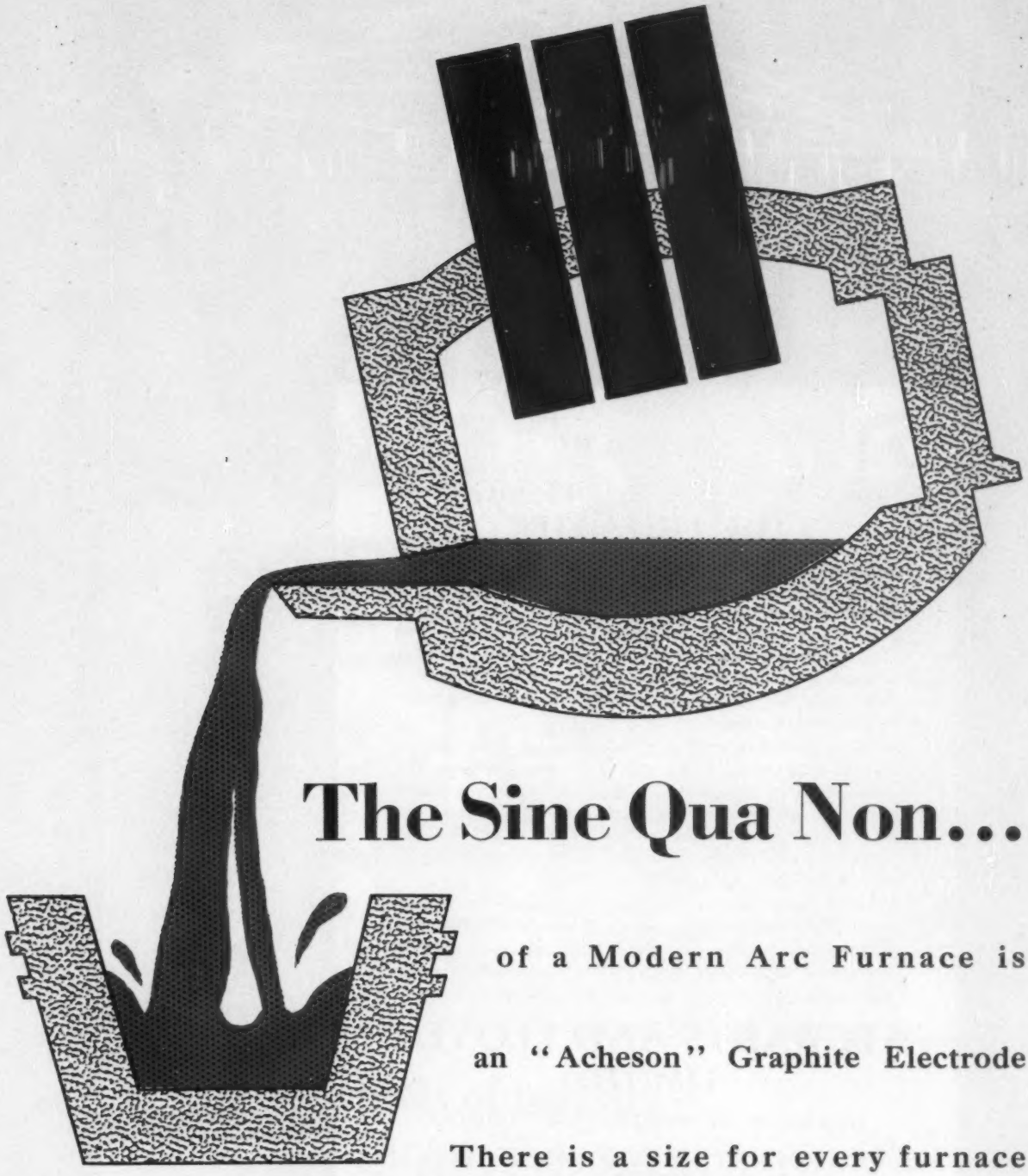

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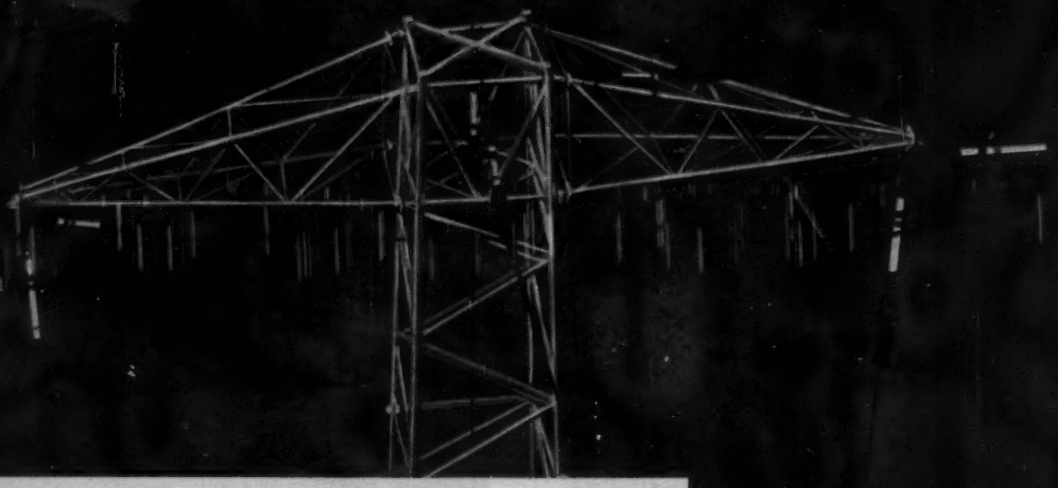


SCIENCE

AND THE STEEL TUBE AGE : 4

THE PULLMETER

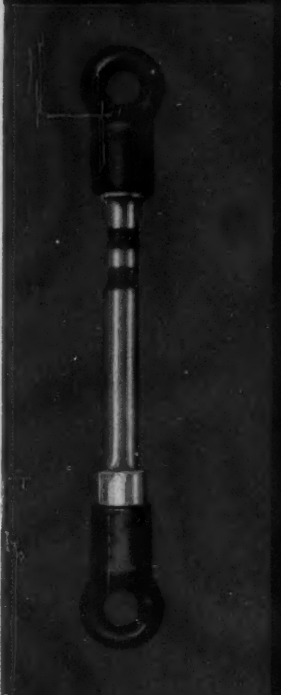
In the testing of structures and in many other forms of research and development, it is most important to be able to measure pulls with accuracy.

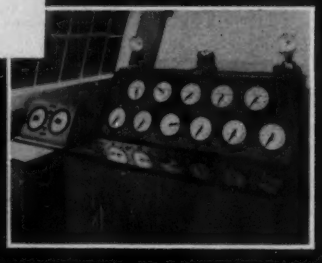
The Pullmeter, designed and made by the instrument section of our Department of Research and Technical Development, is based upon the well-known principle of the differential transformer, but so developed that its accuracy is not impaired by variations in temperature and voltage.

In the illustration a number of Pullmeters are being used to measure loads applied to a transmission tower under test. The simple electrical 'transmitter' of the Pullmeter is housed in a steel tube shackled into the ropes applying the load. The very small extensions of the steel tube under tensile loads are transmitted electrically to the test-house where the loads, expressed in tons, are indicated on dials.

Basically, the device within the Pullmeter transmits to a remote indicator the changes of dimensions of a few thousandths of an inch and is therefore useful in many other aspects of research where small dimensional changes are to be measured.

Right: A Pullmeter. Below right: Load and deflection indicators





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Nos. 125 and 155 roller guides fitted in a 27 1/2 in. (700 mm.) diameter, three-high stand for rolling 2 3/4, 3 3/16, 3 9/16, 4, 4 3/8 and 4 7/8 in. (70, 80, 90, 100, 110 and 124 mm.).

1 The entry friction guides are rigidly clamped into the guide box. They are intended to lead the oval to the groove in the roller, to protect the rollers against overloading, and to straighten bent rods.
The groove in the entry guides is made about 1/8" wider than the oval.

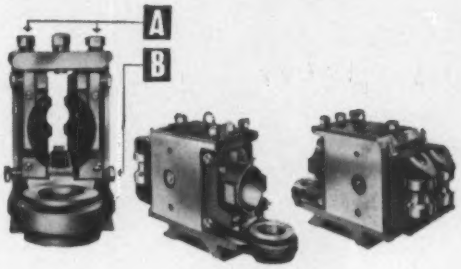
2 The rollers are mounted on leaf springs, which can be adjusted by means of the screws "B", and hold the oval steadily even if there should be some slight variation in the thickness of the oval.

3 If the thickness of the oval should vary, the springs of both rollers yield an equal amount, so that the oval remains in the centre of the groove.

4 To tilt the oval, the screws "A" are adjusted. One roller will then be lifted as much as the other is lowered.

5 As the oval is held very rigidly, the leader oval for wire rod may be thick, unless other circumstances call for a thinner oval.

6 The roller guide assemblies are narrow, and all screws that require adjustment during rolling are accessible from the front of the mill. No lateral space outside the guide box is therefore required for gaining access to the set screws, and the guide box assembly can thus be located close to the mill housing.



7 As the groove in the entry guides is wide and nothing but rolling friction acts on the oval, the latter is very easily introduced into the pass, and there is practically no risk of scratching the bar.

8 The roller guide may be used not only for leader and drawing oval passes but also for edging flats as well as for rolling squares, hexagons, octagons and various other sections, for instance in reduction passes for hexagon. It is suitable for all types of rolling mill. An important advantage is that the roller guide enables repeaters to be used in rolling plump leader-ovals.

PS *Practically speaking, every bar and wire rod mill in Scandinavia uses roller guides of our design.*

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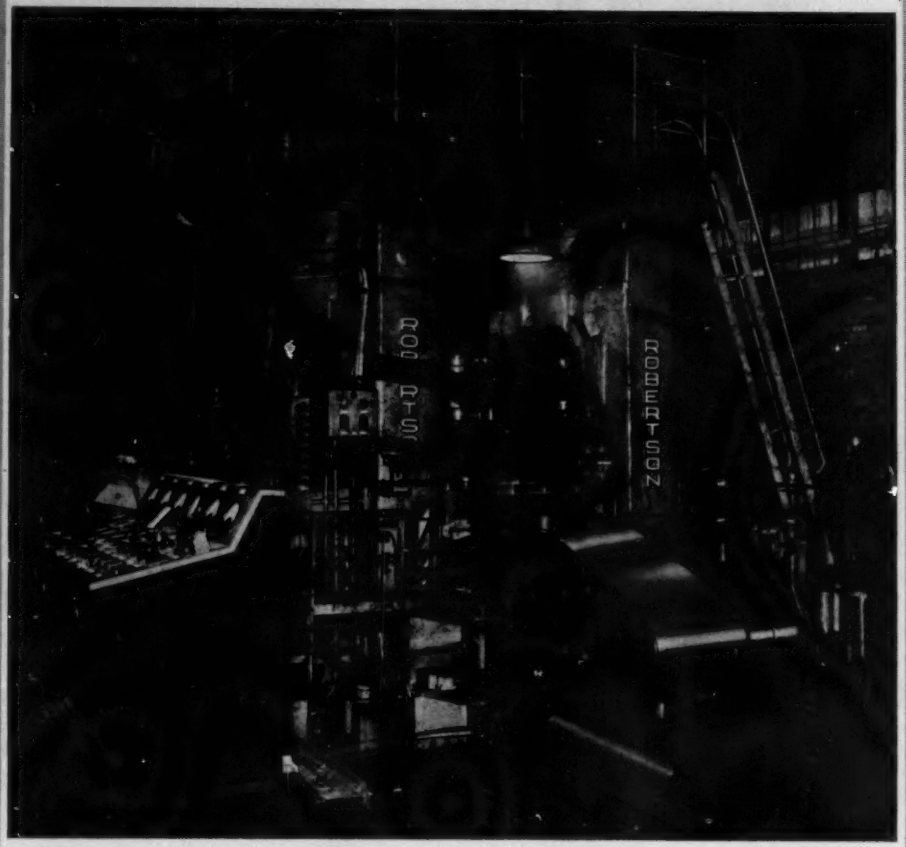

Illustration shows a 15″ and 37″ x 60″ Reversing Four-high Cold Rolling Mill for soft, and alloy steel strip up to 50″ wide. Maximum rolling speed 1,200ft./min.

Photograph by courtesy of Messrs. Richard Thomas & Baldwins Ltd.

EQUIPMENT

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Two words that mean the best roof lighting — Corrugated 'Perspex'

Corrugated 'Perspex' roof lighting installed in the works of Mitchell, Russell & Co., Bonnybridge. Photographs by arrangement with Newton, Robertson & Co. Ltd., Glasgow.

CORRUGATED 'PERSPEX' is the answer in all buildings, large and small, where good light conditions are important. Corrugated 'Perspex' acrylic sheet is tough, durable, and gives a very high transmission of daylight. It means good health, good morale and increased efficiency in factories and workshops — as well as reduced lighting costs.

Corrugated 'Perspex' is light, easy to handle and inexpensive to install. It will stand up to weather conditions in any part of the world. It is not harmed by the corrosive atmospheres in industrial areas. It is available in a wide range of profiles.

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CP.123/1

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'Perspex' is the registered trade mark for the acrylic sheet manufactured by I.C.I.

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ICI

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by

B T-H

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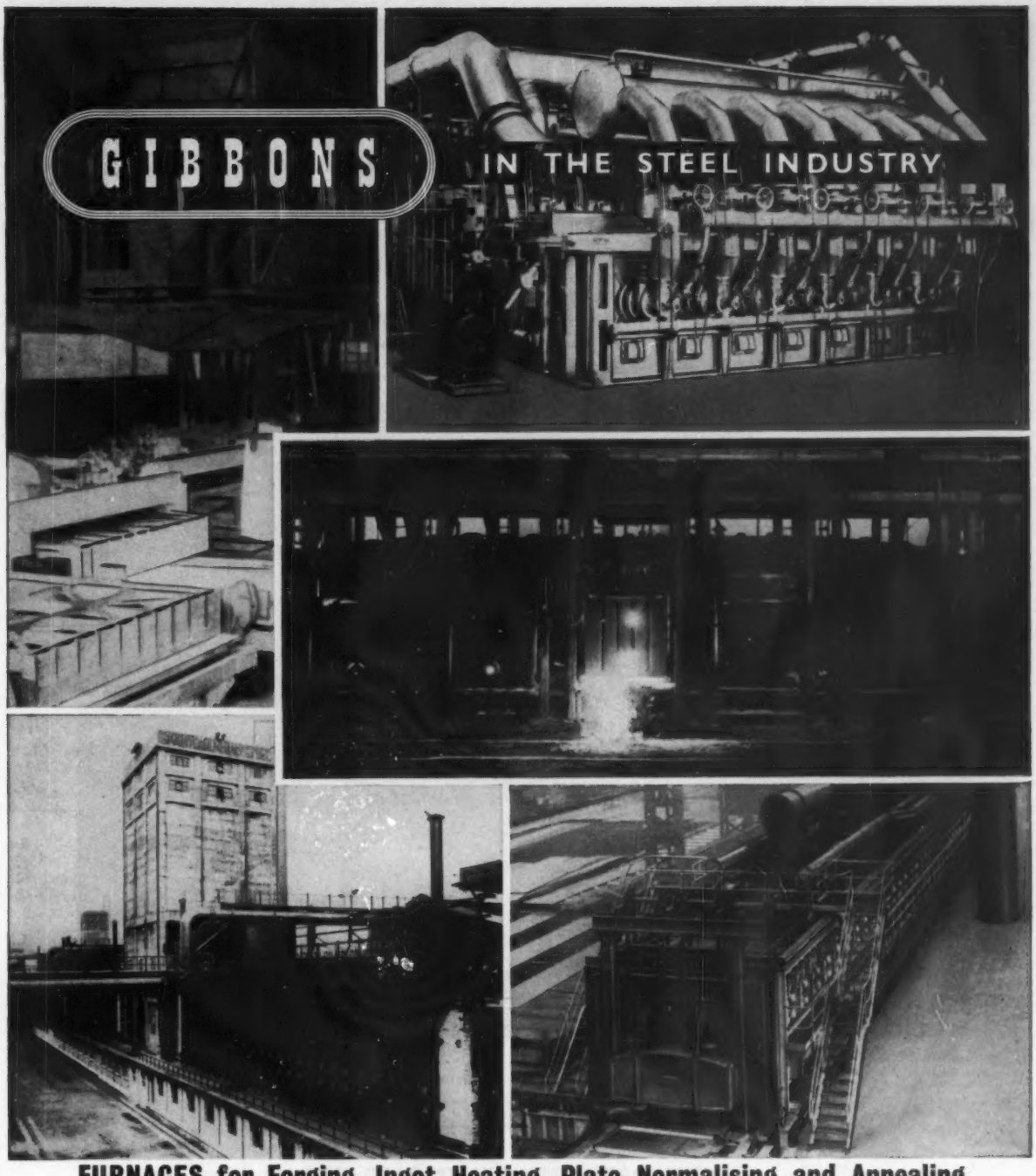

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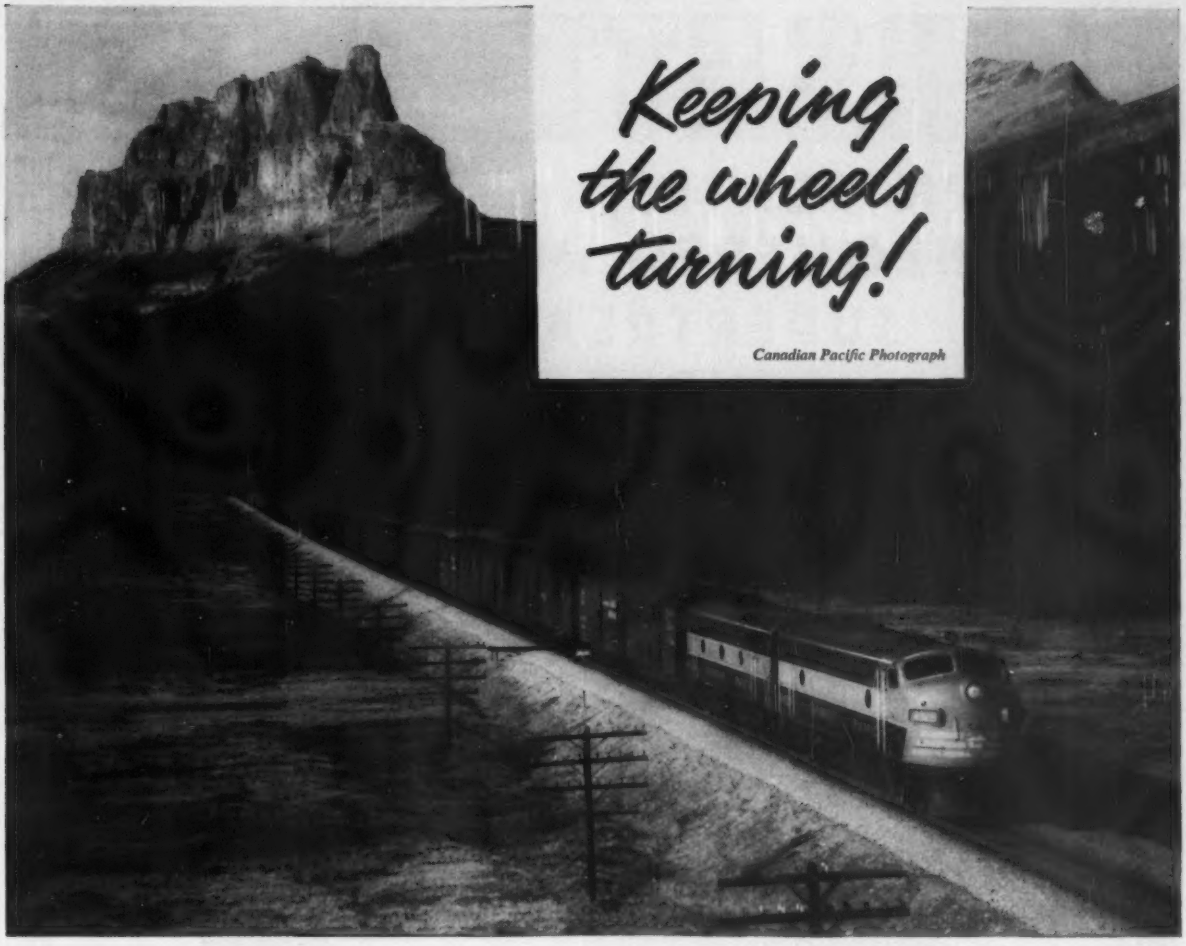

Two 40 ton G.W.B.–Leone Tagliaferri melting furnaces ordered by Canadian Steel Wheel Company, Montreal

In the face of intense competition from American and German firms G.W.B. Furnaces have won an order worth about 500,000 dollars for two 40 ton capacity Direct Arc Steel Melting Furnaces. Built to the designs of G.W.B.'s Italian associates, Leone Tagliaferri & Company, Milan, the complete furnaces will be built in England, except for the refractories and some ancillary equipment. The furnaces will have a 16′ diameter shell, and will be rated at 17,500 KVA through an off-load tapped transformer. Three 18″ diameter graphite electrodes are fitted in each furnace. These will be controlled hydraulically by the patented Tagliaferri system, which gives finer control and faster electrode operation than the motor operated method.

THE BACKGROUND BEHIND THIS ORDER

As from January 1st 1958 no cast iron wheels are to be fitted to Canadian or American rolling stock. Wheels will, therefore, be of steel, either cast or forged. Two American controlled companies are going forward with plans to manufacture cast steel wheels. The Canadian Steel Wheel Company will manufacture wheels of the forged type.

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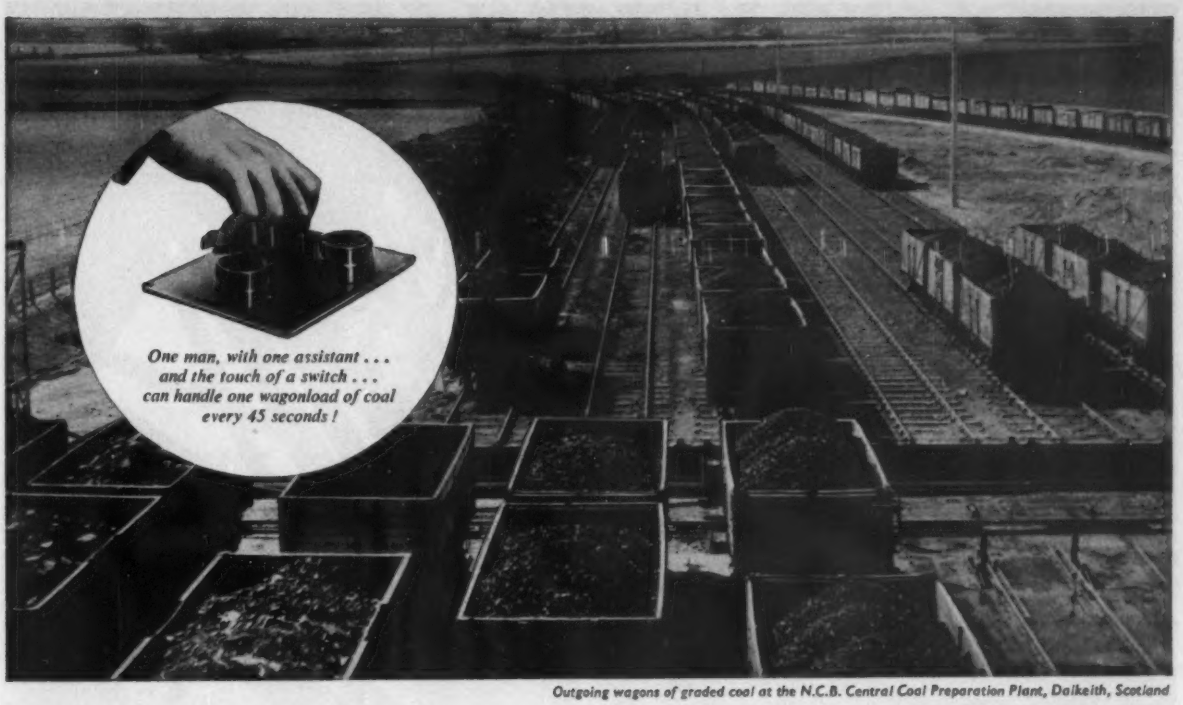


Outgoing wagons of graded coal at the N.C.B. Central Coal Preparation Plant, Dalkeith, Scotland

NEW APPROACH TO WAGON HANDLING

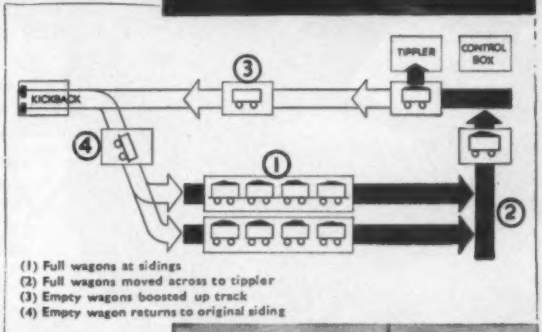
. . . Mitchell system means smaller sidings, quicker turnround, less gear, greater safety

How many men work on your coal sidings? How many locomotives or capstans? What space is wasted by sprawling tracks? How much tonnage can you handle per hour?

The generally unsatisfactory answers given to such questions as these inspired the design of the Mitchell system of wagon handling—a mechanical, electrically-controlled system that offers remarkable scope for increased efficiency at power stations, collieries, coal preparation plants, steelworks, etc., and other centres of industry possessing marshalling yards.

The Mitchell system can be operated by two men. It takes wagons from the arrival sidings, loads or unloads them, weighs them and re-marshals ready for departure. Wagons can be emptied and returned to the same siding they arrived at "full" so that one track is used for full and empty wagons. No internal shunting, no additional motive units, no man-handling other than initial uncoupling and final recoupling, are required. The system has no limit to size or capacity and can easily handle the 1000 tons or more of coal per hour which is now being called for. And it does it with the highest degree of safety, in all weathers, round the clock if needs be.

By demanding no more than half the space occupied by traditional balloon sidings, the Mitchell system makes possible the erection of new plant on sites hitherto unsuitable, with very large savings in initial and later costs. Its flexibility makes it adaptable to any individual handling problem. Installations are already at work for the National Coal Board and the British Electricity Authority. The thoroughgoing efficiency and economy of the Mitchell system puts it far in advance of any traditional method and establishes it as the system of the future.



(1) Full wagons at sidings
(2) Full wagons moved across to tippler
(3) Empty wagons boosted up track
(4) Empty wagon returns to original siding

An installation at the British Electricity Authority Freemens Meadows, Leicester, handling 800 tons of coal an hour. The site is limited in area and normal methods of working with balloon sidings would be impractical. The pictures show the traverser pulling an incoming truck on to the transfer rail and an emptied wagon being returned to the siding by the 'kickback'.

MITCHELL

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EC/M22

Pattern of protection

The persistent upward trend of maintenance costs is a bugbear that can throw any budget out of gear and the cost of genuine red lead is one of the contributory factors. Now leading authorities specify "Superlative" Metal Primer to offset much of this cost. "Superlative" ensures complete protection for all ferrous metals. And as well as saving in initial material costs it has the advantages of easier, quicker application than red lead and greater coverage. Resultant reduced labour charges emphasize further the lower maintenance costs effected by "Superlative" Metal Primer.

'Superlative' Metal Primer prevents corrosion economically. *Our Techniservice will gladly answer all enquiries*

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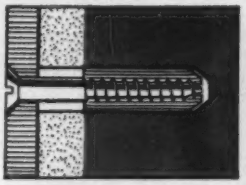
Screw Fixings

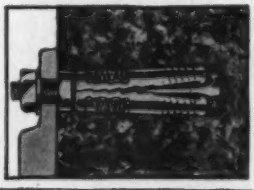
Use the famous RAWLPLUG for neat, firm fixings in brick, stone, etc. All sizes up to ¾" diameter Coach Screws. Rawlplugs are waterproof and unaffected by climatic conditions.



Rawlplug WHITE BRONZE PLUGS are specially suitable when the fixing is subject to very high temperatures, such as the outer brick coverings of furnaces. Use also for under-water fixtures.

Bolt Fixings

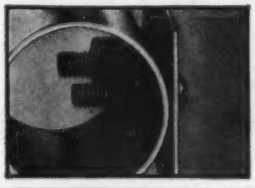
For bolting down machines, use RAWLBOLTS, a dry fixing that grips by expansion. No cold chiselling, no waiting for cement to harden. Sizes up to 1" bolt diameter.

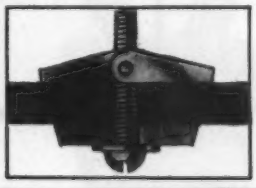


Use Rawlplug BOLT ANCHORS for bolting down in extremely wet or corrosive situations. Caulking completely seals the anchorage. Use also for anchoring Diesel Generators, Power Hammers, etc.

Cavity Fixings

Screwed up from the front the amazing RAWLNUT forms its own rivet head behind the material—airtight, watertight, vibration-proof, squeak-proof! For all thin or hollow materials.





For ceilings of lath and plaster, plasterboard, etc., use Rawlplug SPRING TOGGLES. The inserted Toggle springs open behind the material, spreading the load over a wide area.

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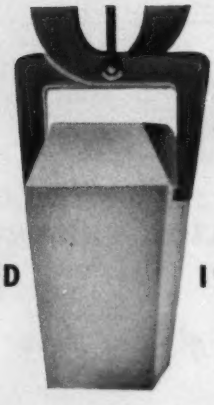

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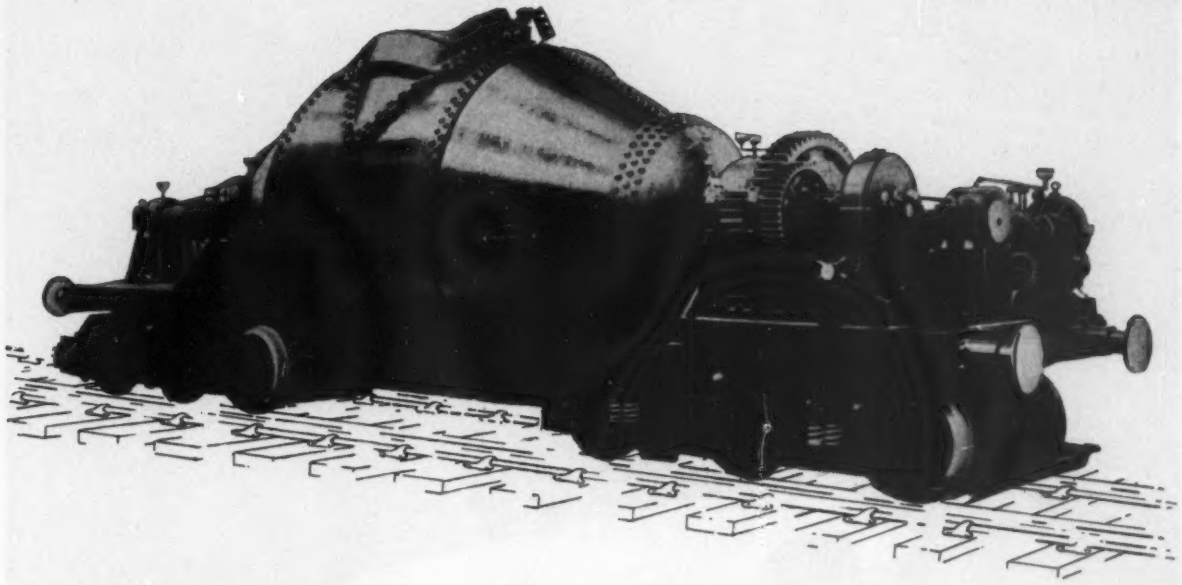

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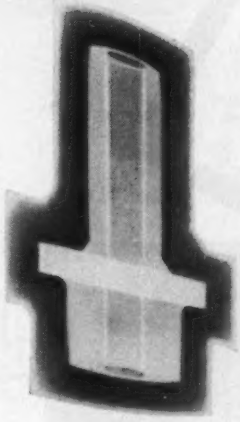
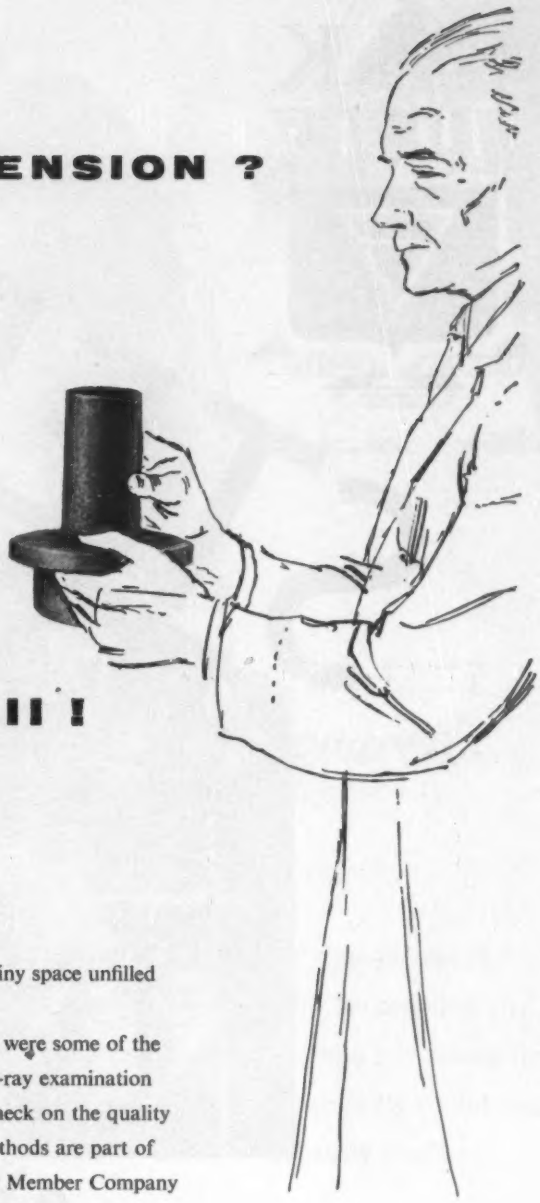


...tells all !



Space/time ? In a casting, or a forging, a tiny space unfilled will destroy, if it is not found in time.
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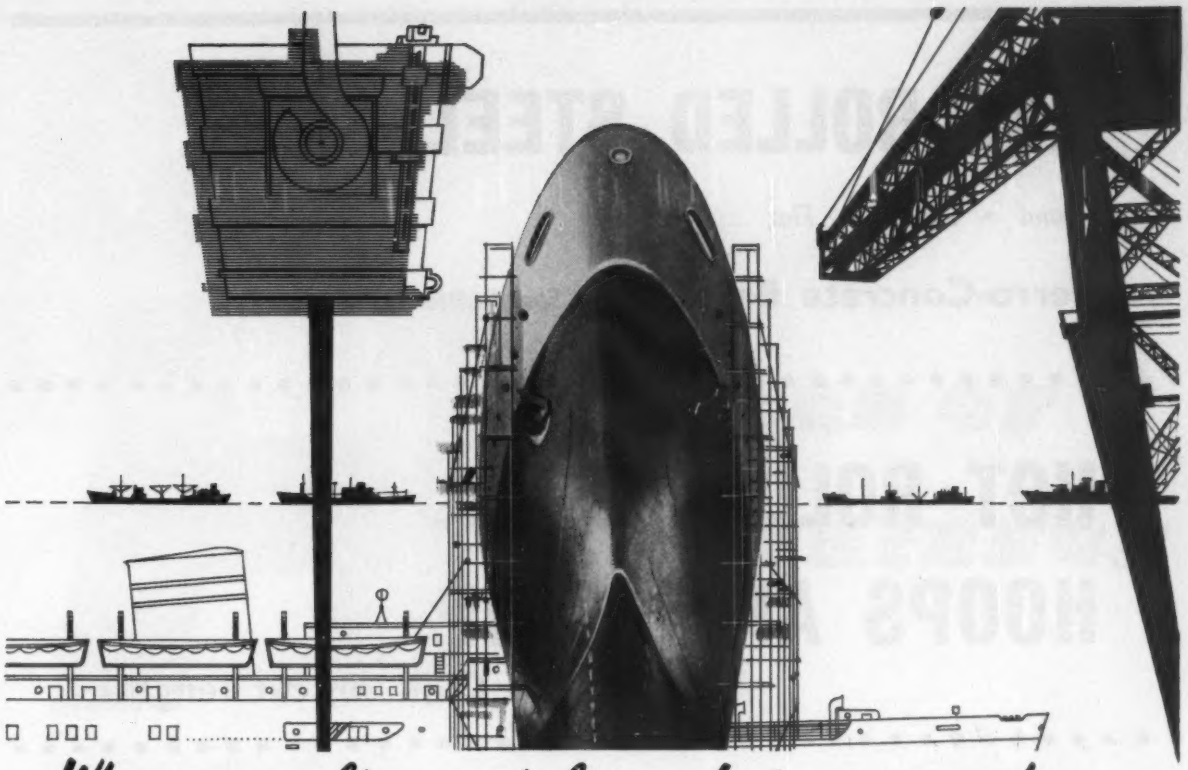

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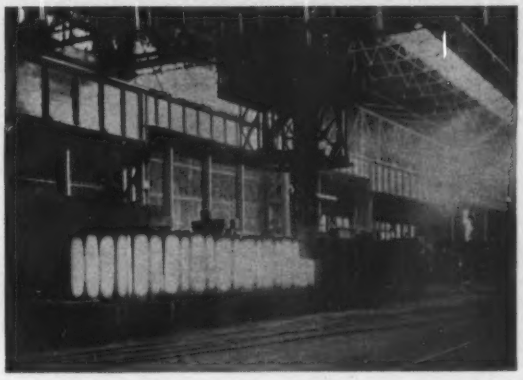

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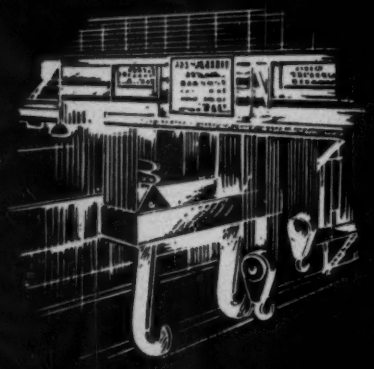

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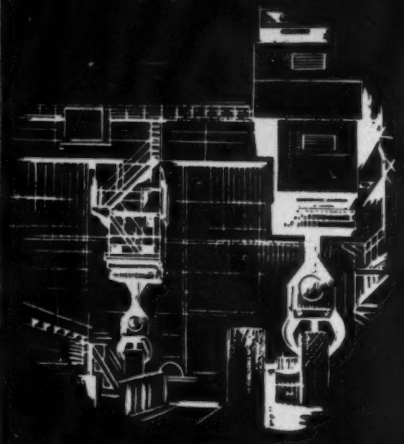

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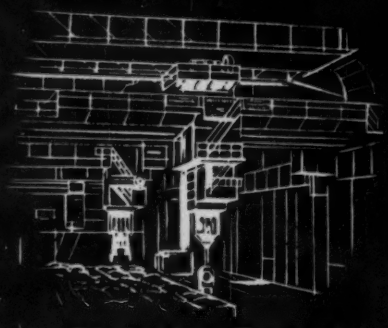

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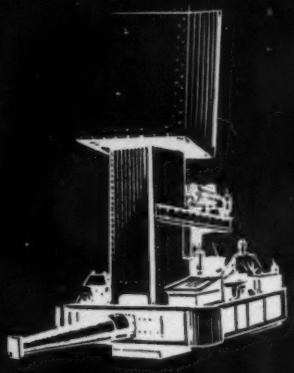

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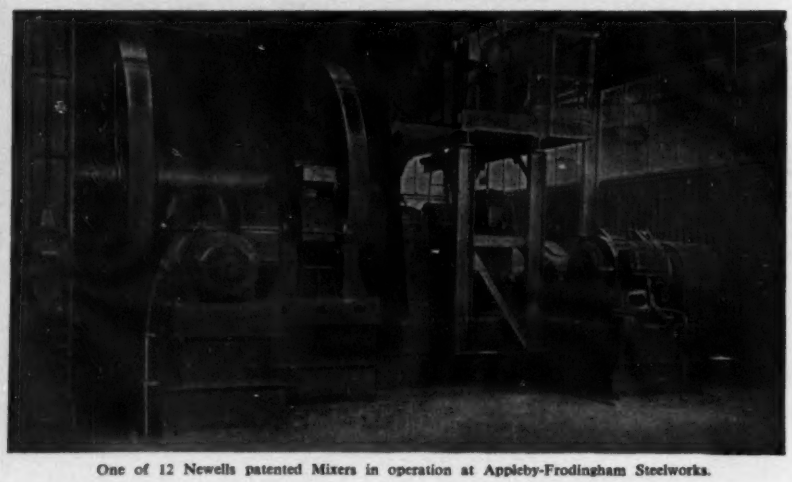

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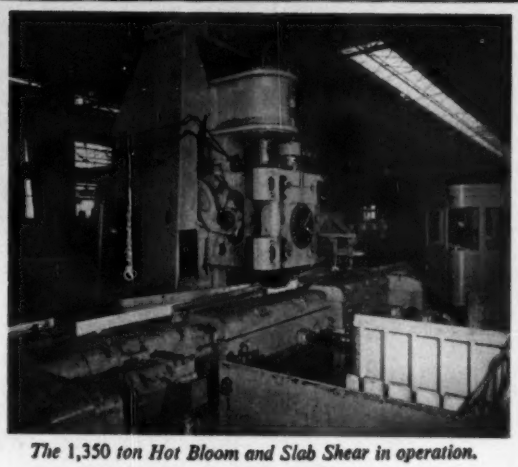
THE IRON AND STEEL INSTITUTE, 4 GROSVENOR GARDENS, LONDON, S.W.1

The Blooming and Slabbing Mill in action at Lackenby.



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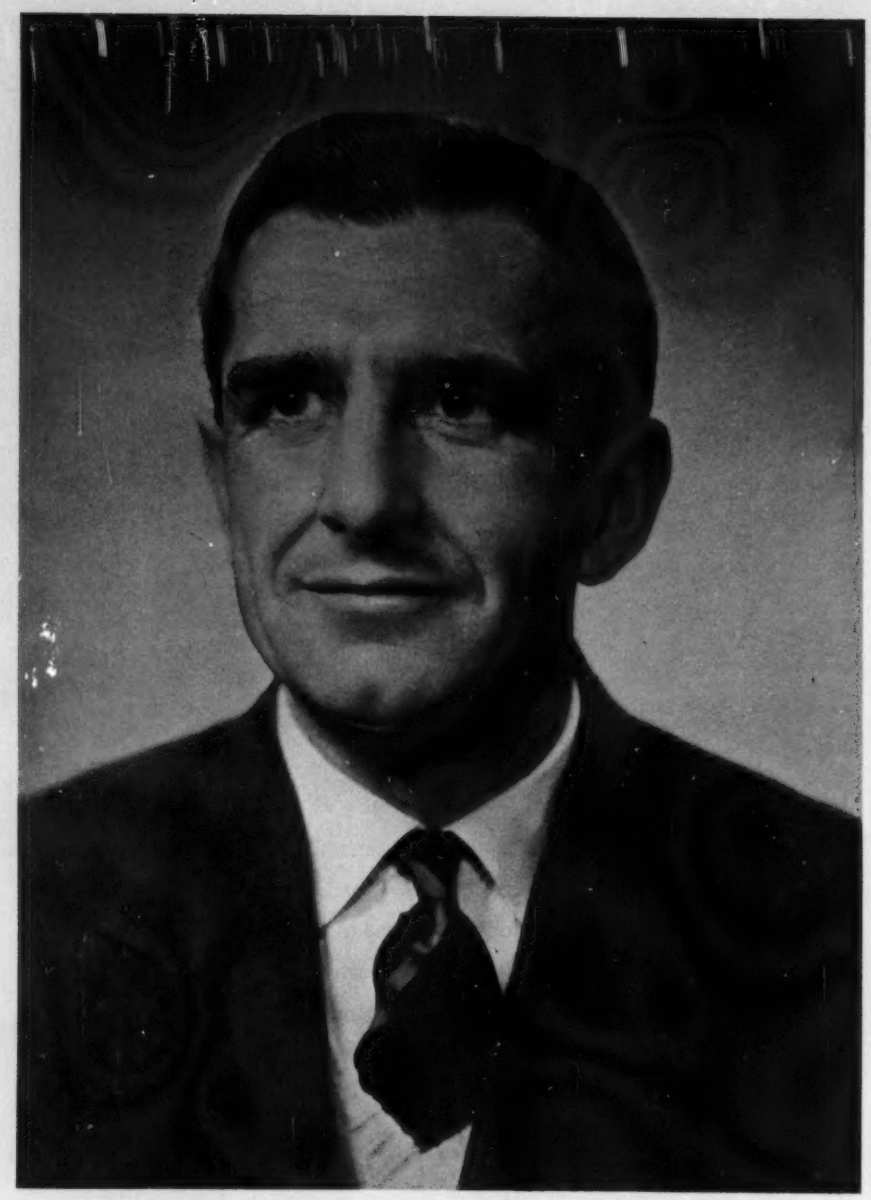
A. H. NORRIS

ARTHUR HUBERT NORRIS was born in 1915 and educated at Cheltenham College. He started work at the Normanby Park Steel Works of John Lysaght Ltd. as a student in 1934. Three years later he was appointed Assistant Mill Manager, and he became Mill Manager in 1943. A new cogging and continuous mill was built in 1950 as part of the company's post-war reconstruction and development programme, and Mr. Norris was made the first manager of the new mill. In 1955 he was promoted to Assistant Works Manager (Production), and at the beginning of this year he was appointed General Sales Manager.

Sport has played a large part in Mr. Norris's spare-time activities. He has played for Lincolnshire at cricket in the Minor Counties Competition, both before and after the war, and he has also represented the county at rugby football.

Mr. Norris joined The Iron and Steel Institute as an associate member in 1937, and became a full member nine years later. He was awarded a Williams Prize in 1953 for a paper published in the *Journal* on "Soaking Pit Practice at the Normanby Park Steelworks of John Lysaght Ltd." He is also a member of the Lincolnshire Iron and Steel Institute, and was elected to its Council in 1945. Four years later he became a Vice-President, and he was elected President in 1957. As such he will serve as an Honorary Member of Council of The Iron and Steel Institute during his term of office.



A. H. Norris

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PAPERS AND REPORTS ON
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Studies of the Permeability of Blast-furnace Burden Materials

By J. M. Ridgion, B.Sc., A.R.C.S.

SYNOPSIS

Previous work on the relationship between pressure drop and air flow in beds of broken solids is considered in the light of experimental work carried out at the B.I.S.R.A. North East Coast Laboratories.

Various discrepancies are noted with special reference to the peculiarities of layered systems of different sizes, and it is concluded that quantitative predictions of the behaviour of beds of solids are not reliable. Particular cases can only be assessed by direct experiment, save in the simplest cases. 1526

INTRODUCTION

KNOWLEDGE of the relationship between gas flow and pressure drop through beds of granular solids is of great importance in understanding the physical and chemical processes of the blast-furnace stock column, and several attempts have been made to develop generalized solutions.

The classical work of Furnas[1] of the U.S. Bureau of Mines was carried out on small-scale systems, much of it with spherical particles, and led to a number of generalizations which have subsequently served to guide blast-furnace operators seeking to improve the permeability of their burdens.

A general equation of flow may be considered

$$V = K p^n$$

where p = pressure drop per unit height
V = volume flow per unit area
n may be expected to lie between 0·5 (fully turbulent flow) and 1·0 (streamline flow)
K is a constant for a given bed.

For beds made up of particles of uniform size, the pressure drop for a given value of V will be less, the larger the particles and the higher the fractional voidage. Voidage depends on such factors as particle shape and mode of packing rather than absolute size.

For beds consisting of mixtures of two or more fractions each of uniform size, Furnas put forward certain generalizations which have greatly influenced subsequent thought:

(*a*) Resistance of a binary system is greater than the resistance of a system of more than two components if the smaller constituent is the same in both cases and its ratio to the larger components is kept the same.

(*b*) Therefore, the resistance of a system of two component sizes may be lowered by displacing part of the large constituent with particles of smaller size, but larger than the small constituent.

(*c*) A resistance maximum occurs when the voids formed by the large constituent are approximately equal to one-fourth; i.e. if the value of the normal voids of the large constituent V% is multiplied by the fraction of the large constituent at the point at which the maximum occurs x, then the value is approximately 25% ($V.x = 25$%).

(*d*) If a system of a mixture of two sizes has the constituent sizes separated into distinct layers, the combined resistance of the two layers will be less than the resistance of the mixed bed.

This last statement has been taken to imply that for a mixture of particles of widely varying sizes, separation into two size fractions which are then layered will increase overall permeability. Such a result was not claimed by Furnas, who specifically stated that generalization (*d*) was not necessarily true for systems of many sizes.

Ergun[2, 3] has proposed a general formula for pressure drop in a packed column such as the blast-furnace (ignoring viscous energy loss, which he shows to account for less than 2% of the pressure drop he obtains):

$$\frac{dP}{dL} = 4{\cdot}67 \times 10^{-3}\left(\frac{1-\epsilon}{\epsilon^3}\right)\rho U^2/D_p$$

where P = pressure, lb/in²
L = height of bed, ft
ϵ = fractional voidage
ρ = density of gas, lb/ft³
U = gas velocity (based on empty shaft), ft/s
D_p = particle size, in.

Paper IM/A/36/57 of the Burden Committee of the Ironmaking Division of the British Iron and Steel Research Association, received on 22nd January, 1958. The views expressed are the author's, and are not necessarily endorsed by the Committee as a body.

Mr. Ridgion is Deputy Head of the Association's Ironmaking Division.

In a material of mixed sizes, D_p is to be obtained from the following formula:

$$D_p = \Sigma X_i / \Sigma (X_i / D_i)$$

where X_i is the fraction by volume occupied by solids having the size D_i.

In Ergun's formula, the size grading of the solids affects the pressure drop by the factors

$$\frac{1}{D_p} \text{ and } \left(\frac{1-\epsilon}{\epsilon^3}\right).$$

From the definition of D_p it is easy to show that $1/D_p$ is the same for two superimposed layers as for the complete mixture of the two. In general, mixing of two size gradings will result in a lower voidage than the average as there will be a tendency for the smaller component to fill voids in the larger, and this will result in higher value of $(1-\epsilon)/\epsilon^3$ for the mixture. Moreover, it can be shown that $(1-\epsilon)/\epsilon^3$ is higher for a mixed system than for two layers of differing voidage, even if the total void space in the system remains the same after mixing.

Ergun's work, too, therefore suggests that advantages may be gained in blast-furnace operation by dividing the burden into coarse and fine fractions and charging them in separate layers.

The specific influences of layer charging were also studied by Nixon and Maw,[4] using normal blast-furnace materials in a 3-ft dia. container. Most of their results were in accordance with expectation, but in certain cases they found higher permeabilities for mixed beds than for superimposed layers.

Nixon's work was designed to meet the specific requirements of one company using specific raw materials, and it seemed desirable that further work be undertaken of a more general nature. An apparatus substantially identical with that of Nixon was set up at the B.I.S.R.A. North East Coast Laboratories and suitable techniques were developed. The apparatus and experimental procedure are described in the Appendix.

RELATIONSHIP BETWEEN PRESSURE DROP AND FLOW

In the general flow equation referred to above, $V = K_p^n$, n is an index of flow conditions with a range 0·5–1·0. With his wide variety of experimental conditions, Furnas obtained values throughout this range, but beds of irregular solids passing flow rates of the order encountered in shaft furnaces show substantially turbulent flow with indices approaching 0·5. Nixon reported values in the range 0·53–0·64, and B.I.S.R.A. results have been mostly between 0·5 and 0·6. From time to time values slightly below 0·5, down to 0·46, have been obtained, which are not in accord with aerodynamic theory. Painstaking checking of the experimental conditions has not led to any explanation, but the discrepancies have little effect on the relative permeabilities of different charges.

The permeability formula

$$P = \frac{F}{A}\left(\frac{h}{s}\right)^n$$

where P = permeability, B.P.U.
F = volume flow, ft³/min (S.T.P.)*
A = cross-sectional area of bed, ft²
h = bed height, in.
s = pressure differential, in. w.g.
n = flow index of order 0·5–0·6.

was developed in connection with the study of flow through sinter beds[5] and is equally convenient as a means of characterizing the performance of a bed of furnace raw materials over a range of gas flow.

However, permeabilities in multi-layer systems cannot be averaged, even if the various layers behave independently of one another. Two such layers of height h_1 and h_2 and permeabilities P_1 and P_2 would show a combined permeability P such that

$$\frac{h_1 + h_2}{\sqrt[n]{P}} = \frac{h_1}{\sqrt[n]{P_1}} + \frac{h_2}{\sqrt[n]{P_2}}$$

but in all cases P must lie between P_1 and P_2 in the absence of interaction between the two layers or their flow patterns. For this reason it is sometimes more convenient to quote a pressure-drop figure as well as a permeability. The expression Δp_0 in the tables below is the pressure drop in in. w.g. per foot of bed corresponding to a flow of 1500 ft³/min free air, equivalent to 3·5 ft/s, a figure of the general order of the flow rate in the blast-furnace stack.

LAYERING AND MIXING

Taking two materials or size fractions with permeabilities $P_1 > P_2$, one would expect any system built up of layers of the two constituents to have a permeability P_L such that $P_1 > P_L > P_2$. On the grounds advanced in the Introduction, one would expect any mixture of the two components to have a permeability P_m such that $P_1 > P_L > P_m$, and in most cases $P_2 > P_m$.

In fact systems investigated have confirmed and denied almost every one of these expectations.

Example I

Coke	Permeability, B.P.U.	Δp_0
Large fraction — 1½ + 1 in.	765	0·71
Small fraction — ¾ + ½ in.	568	1·15
3 layers (*L*, *S*, *L*)	610	1·06
Mixture	652	0·94
Calculated for 2*L* + 1*S*	—	0·86

Here the mixture is more permeable than the layered system.

Example II

Three ores used in a N.E. coast plant were studied, the initial size analyses being as follows:

Size Fraction, in.	Northants, %	Djerissa, %	Grängesberg, %
+ 1 — 3	44·0	71·0	77·0
+ ½ — 1	6·5	5·7	5·7
+ ¼ — ½	14·5	10·0	9·0
+ ⅛ — ¼	8·0	4·5	3·7
+ ¼ — ⅛	4·0	2·8	1·8
+ ½ — ¼	6·5	2·8	1·0
— ½	16·5	3·2	1·8

Each ore was screened at 1 in. and observations were made on the large and small fractions, on the complete mixture as received, and on various layered systems:

		Northants	Djerissa	Grängesberg
Large fraction	P	720	735	750
	Δp_0	1·1	1·0	1·2
Small fraction	P	260	460	365
	Δp_0	8·7	3·0	4·5
Mixed	P	150	356	610
	Δp_0	26·5	4·65	2·75

* S.T.P. = 60° F, 30 in. Hg.

		Northants	Djerissa	Grängesberg
Weighted mean of L and S	Δp_0	5·4	1·6	1·95
Layered system, ft		S 1½	S 1¾	S ¾
		L ¾	L 1¼	L 1¼
		S 1		
		L 1		
Observed	P	236	375	415
	Δp_0	9·9	4·6	3·05
Weighted mean of L and S	Δp_0	5·4	2·2	2·45

When a mixed size grading is separated into two superimposed layers, the total resistance must be determined by the following factors:

(1) The resistance which each of the layers would show in isolation
(2) The distortion of the flow pattern at the interface
(3) The effect of changes in size grading of the layers adjacent to the interface arising from interchange of material brought about by gravity or aerodynamic forces.

If the height of such a twin-layer system be increased indefinitely, the interface effects must reach negligible proportions, the overall pressure drop per foot (Δp_0) becoming a weighted mean of that for the isolated large and small layers. Such weighted means may be compared with observed values to give some indication of the disturbances due to superposition.

For the ores considered the mixed beds are less permeable than the weighted means and in the first two cases even less than the small constituent alone. Again, the three-layered systems are less permeable than would be expected, the pressure drops being respectively less than, equal to, and greater than the corresponding figures for the mixed ores.

In contrast to the large fractions, the small components differ greatly among themselves in permeability and, correspondingly, in the proportion of $-\frac{1}{16}$ in. The high proportion of this in the Northants ore may be presumed to increase the packing density in the mixture and also to undergo ready transfer across the interfaces in the layered systems.

Example III

The three ores in appropriate proportions (60 : 13 : 37) were next mixed with limestone to correspond to the blast-furnace charge and the whole screened at 1 in.; + 1 in., − 1 in., and mixed burden material was used together with furnace coke either intimately mixed or charged in alternate layers, and the following permeabilities were observed:

Burden size fraction	+ 1 in.	All	− 1 in.
Mixture with coke	1045	710	500
Layered with coke	1080	395	340

The coke, being graded, was of comparable size with the large ore and good permeabilities were found. When the small ore was present it was noteworthy that the layered system was even worse than the mixture. This suggests that the very small fractions are present in sufficient quantity to fill up a major proportion of the voids in the ore burden but insufficient to block all the voids in the ore plus coke mixture.

INFLUENCE OF SPECIFIC FRACTIONS ON MIXTURES

Some experiments have been made on the removal from or addition to complex mixtures of a particular size fraction of one of the constituents.

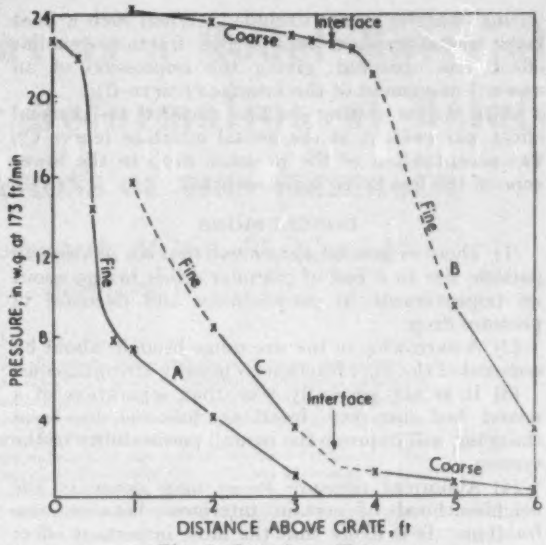

Fig. 1—Interface effects

A blast-furnace burden made up of 27% coke, 31% sinter, 14% soft ores, 7% hard ores, and 21% of home ore and stone showed a permeability of 470. Of the sinter used, 7% was − ¼ in.; the replacement of this by + ¼ in. sinter increased the permeability of the entire mix to 645.

Rather more difficult to understand is the influence of limited additions of a small size fraction to large coke which may increase the overall permeability:

+ 1 in. coke	900
with 20% + ½ − 1 in.	1030
+ ½ − ¾ in. coke	568
with 20% + ⅜ − ½ in.	623

Such a result is in direct contradiction to the work of Furnas and Ergun.

INTERFACE EFFECTS

One series of experiments has been carried out under conditions allowing a closer study of the immediate neighbourhood of an interface, the standard pressure tappings of the voidometer being supplemented by a series of closely spaced pressure probes embedded in the material. Only sinter has been used for this work, the two fractions ± ½ in. being about equal in quantity and of the following size gradings:

+ ¼ in. fraction	− ¼ in. fraction
57% + ½ − 1 in.	53% + ¼ − ½ in.
24% + 1 − 1½ in.	32% + ⅛ − ¼ in.
19% + 1½ in.	15% − ⅛ in.

Various layer combinations were used, but the most characteristic feature observed is illustrated in Fig. 1 (curve *A*), which relates to a simple, supposedly uniform layer of − ½ in. material. The departure from a straight line in the lower foot of the bed was detectable with low air flows from the start but was progressively enhanced at normal flows with the passage of time. It would seem that migration of the smallest particles may occur to produce a close-packed system, in this case about 6 in. from the bottom of the layer. This seems to be largely derived from material blown up from the base of the bed, but downward migration

during charging is not excluded. When such a fines layer was superposed on a $+\frac{1}{2}$ in. fraction a similar effect was observed, giving the impression of an upward movement of the interface (curve *B*).

With coarse resting on fine material no unusual effect was evident at the actual interface (curve *C*), but accentuation of the pressure drop in the lower zone of the fine layer again occurred.

CONCLUSIONS

(1) There is general agreement that an increase in particle size in a bed of granular solids brings about an improvement in permeability and decrease of pressure drop.

(2) A narrowing of the size range brought about by removal of the finer fractions is usually advantageous.

(3) It is not generally true that separation of a mixed bed into size fractions, followed by layer charging, will improve the overall permeability of the system.

(4) Abnormal pressure losses may occur in the neighbourhood of certain interfaces between size fractions. It is likely that the most important effect here is concentration of the smallest material in a layer of fines resting on a coarse layer. Such an effect depends on the distribution of sizes in the fines layer and may be absent if the fines layer is very closely graded.

(5) Adverse effects of layered systems will generally become less important as the thickness of the constituent layers is increased.

(6) The effects of segregation on permeability of granular material systems will be greater with high and irregular gas flow and where the bed undergoes downward movement.

(7) The flow of gases through beds of irregular broken solids is too complex for quantitative forecasting. Information relating to any specified system can only be obtained by adequate scale study of the system in question.

Acknowledgments

Thanks are due to Mr. J. Docherty and Mr. G. Wilson, who carried out the experimental work at the B.I.S.R.A. Laboratories on which this note is based.

APPENDIX

The apparatus consists of a vertical cylinder 3 ft in diameter and 6 ft $8\frac{1}{4}$ in. high. At the base is a grate and wind-chest connected by a 12-in. dia. main to a fan fan rated at 4000 ft³/min at 2 lb/in². The main is furnished with a butterfly valve to control the flow and an 8-in. orifice for volume measurement. At intervals of 1 ft from the grate there are sets of four pressure tappings connected to piezometer rings for measurement of the pressure drops. Materials are normally charged from a drop-bottom bucket of 7-ft capacity, each layer being levelled with a rake after dumping. To minimize disturbance when using closely spaced internal pressure probes, for example, hand loading by bucket is used.

The experimental method is to increase the air flow in steps from zero to a chosen maximum rate—usually below that at which lifting of the bed takes place—and thence in steps of decreasing flow. At each step pressures at all tappings are measured, together with the orifice differential and correcting factors. Prolonged blowing may be used to ensure that the moisture content of the bed is in equilibrium with the air.

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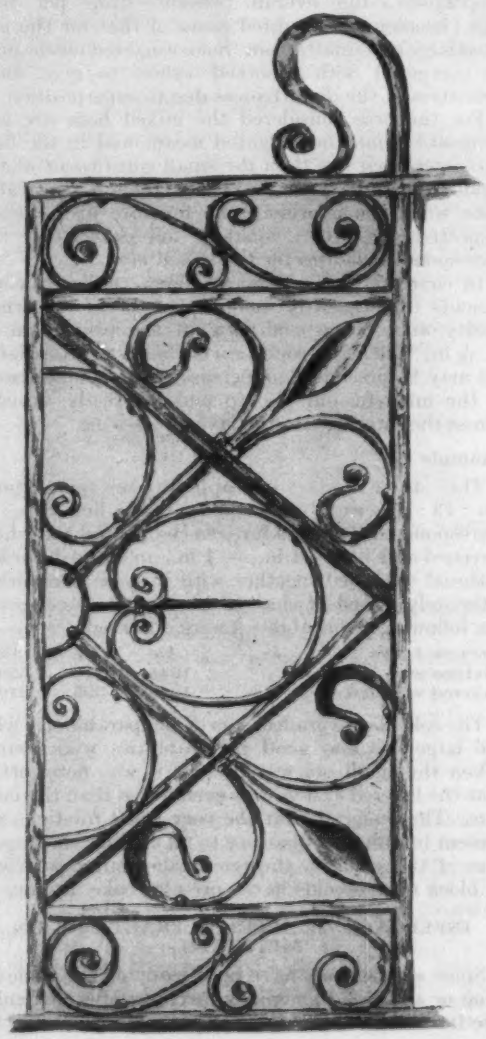
Sussex Ecclesiastical Ironwork — II

The second in the series shows part of the chancel screen at the Church of St. Lawrence, Telscombe. The screen stands 3 ft 10 in. high.



ANDREW CARNEGIE SCHOLARSHIP REPORT

The Use of Paraffin Wax as a Model Material to Simulate the Plastic Deformation of Metals

Part II—PRACTICAL APPLICATIONS OF THIS TECHNIQUE

By J. W. Barton, M.Eng., C. Bodsworth, M.Met., Ph.D., A.I.M., and J. Halling, B.Sc.(Eng.)

SYNOPSIS

The use of paraffin wax has been demonstrated by the study of several metal forming operations.

A close correlation has been obtained between theoretical and practical conditions for direct extrusion with lubricated and rough dies. A wide range of practical friction conditions can be obtained by suitable choice of the deforming surfaces. The effects of extrusion temperature and a temperature gradient in the billet are indicated and deformation patterns are shown for tube extrusion.

The reduction/extrusion-load relationship has been obtained in the case of inverted extrusion. The patterns obtained agree with those for lubricated direct extrusion except for conditions of a rough die face and lubricated container wall. A dead zone was observed only in the latter case.

The technique has been extended to the study of the deformation of material passing through a commercial rolling mill.

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Introduction

IN PART I OF THIS PAPER, the mechanical properties of one grade of commercial paraffin wax were described with reference to tests performed under compressive loading.[1] The properties were found to be sensitive to the strain rate and test temperature, and some evidence of work hardening was detected. The suitability of this material for the study of the behaviour of metals during plastic deformation was indicated briefly by reference to the extrusion process.

The present paper is concerned with the use of the technique and illustrates its application to the study of metal flow during extrusion and rolling. Further tests have also been performed for the evaluation of the properties of paraffin wax under tensile stresses.

ADDITIONAL MECHANICAL TESTS

Tensile Tests

Attempts to study the properties of paraffin wax in tension using the standard tensile-testing equipment available to the authors proved unsuccessful. The specimen failed by fracture before the yield stress was attained owing to slight departures from truly axial loading. An experimental rig was therefore constructed in which the wax specimen was immersed in a thermostatically controlled water tank. The specimen was loaded by admitting water at a constant rate into a container attached via a pulley system to one of the grips, the other end of the specimen being attached to the wall of the tank. The load was measured by a spring balance and the extension of the specimen was indicated by the movement of a pointer attached to one of the pulleys, due allowance being made for the elasticity of the system. The scatter between the results for the yield load was significant, but the indications are that the yield stress in tension is of the same order of magnitude as in compression at similar testing temperatures and strain rates.

The post-yield behaviour could not be studied with this form of apparatus since the dead-loading system caused the specimen to break with a ductile fracture due to the very rapid extension which occurred when the upper yield point was passed.

Compressive Tests

An interesting feature of the yield behaviour in compression has been observed in recent tests. If the load was removed after the yield point had been exceeded, subsequent re-loading resulted in a different stress/strain curve, in which the upper yield point was almost eliminated, as shown in Fig. 1. The decrease in the yield stress was dependent upon the amount of previous plastic strain which the specimen had undergone. For the specimen referred to in Fig. 1, after 8% plastic strain the fall in stress at yield has been reduced from 78·4 lb/in² to 3·1 lb/in². It was apparent that paraffin wax might exhibit strain age hardening similar to the behaviour of mild steel, and deformed specimens were accordingly stored at room temperature to examine the possibility of the recovery of the normal yield behaviour with time. No recovery had been detected after standing for varying periods up to 18 months.

Friction

In forming processes, friction between the deforming tools and the metal has a pronounced effect upon the flow of metal and on the forces of deformation. Because of this, and in view of frictional effects already observed, it was decided to investigate the friction coefficient with a variety of surfaces.

Values of the coefficient of static friction were found by measuring the load registered by a spring balance required to move a square wax block resting on the appropriate surface. The block was loaded with a series of weights between 10 and 40 lb, and by using the relation $F = \mu R$, where F was the force

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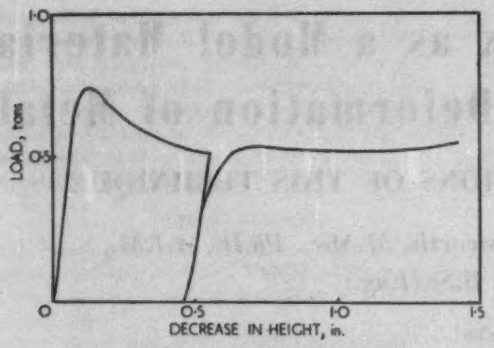


Specimen 3·125 in. dia. × 5·50 in. high
Temperature 26·7° C. Strain rate 0·004/min

Fig. 1—Interrupted compression test

required to move the block and R was the load on the block, the coefficient of friction μ could be calculated. The apparent area of contact between the block and the surface was 5·5 in². The surface of the block was machined flat and the machining marks were removed by scraping with a straight-edge. Dry steel, lubricated steel, coarse emery paper, and knurled surfaces were used, several determinations being made at each load. The results were variable, particularly in the lubricated case, but the average figures are summarized as follows:

Surface	*Coefficient of Static Friction*
Lubricated polished steel (light oil)	Very variable About 0·1
Dry polished steel	0·25
Coarse emery paper	0·5
Knurled steel	0·65

In the model experiments to be described, the significant value is the coefficient of sliding friction, but as the rate of sliding is very slow (e.g. about 0·05 in./min in the extrusion experiments), the static coefficient should be a good approximation to the correct value. It is assumed that these coefficients are not markedly affected by the higher loading encountered in practice.

The range of values given above enables an appropriate surface to be selected for a given model experiment, since the friction coefficients encountered in industrial processes rarely fall outside the range 0·07–0·6.

EXTRUSION

The study of metal flow in the extrusion process is of importance since the flow determines both the deforming forces and the metallurgical properties of the extruded product. The geometry of the process is such that it lends itself to investigation by the split-specimen technique. For simple cases where the die aperture is symmetrical with respect to the billet container, a billet split down the centre with a reference pattern inscribed on one of the faces behaves in an identical manner to a solid billet.

The first known investigation of flow in extrusion was the work of Tresca[2] on lead billets, as part of his investigation of the plasticity of metals. The occurrence of the extrusion defect stimulated research into this process and numerous papers were published in the period from 1920 to 1940 covering the effects of percentage reduction, die angle, friction, etc., and attempts were made with limited success to predict the extrusion pressures from theoretical treatments. The situation at the end of this period has been reviewed by Pearson.[3] Hill[4] has since published a theoretical analysis of direct and inverted extrusion by the method of slip-line fields from which the extrusion load and flow pattern were derived. The load values over a wide range of reductions show good agreement with those obtained in practice and the extrusion loads with plane strain and axially symmetrical conditions, with similar reduction in area, have been shown to be approximately equal.[5] The flow patterns for direct extrusion have been admirably confirmed with Plasticine model experiments.[6, 7]

The theory of slip-line fields applies to plane strain deformation only and whilst it gives (fortuitously) reasonable values of extrusion load, the flow pattern is somewhat different in the more practical condition of axial symmetry. For the same reduction on the centre section the area reduction in axial symmetry is greater, so that there is greater inhomogeneity of deformation and a bigger dead-metal zone. Thomsen[8] has used a purely experimental approach to

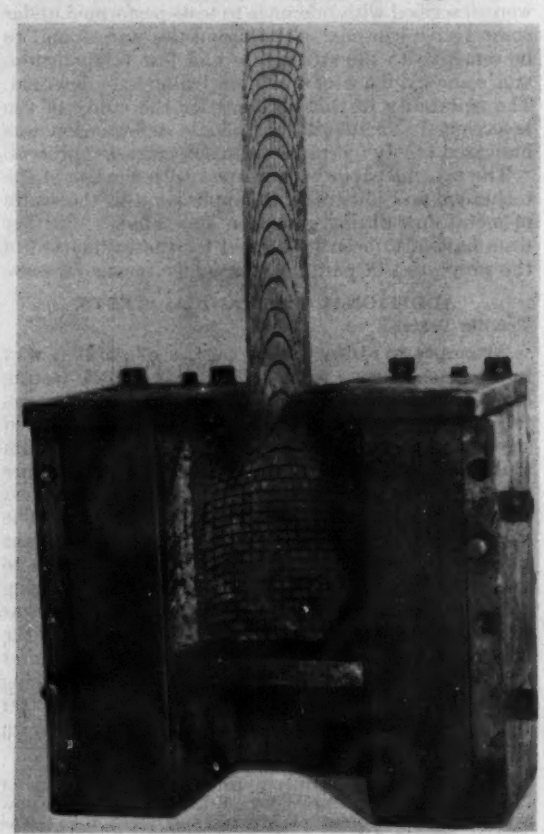


Fig. 2—Extrusion apparatus partly dismantled to show half of split specimen

analyse the stresses in the axially symmetrical case of tube extrusion from a solid billet. He later[9] compared his results with the corresponding plane-strain problem, finding qualitative agreement.

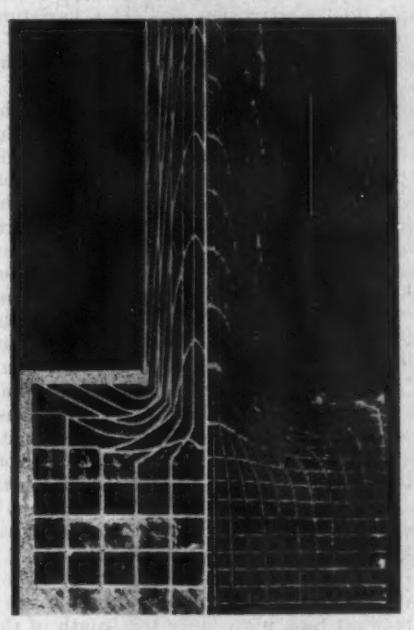
The formation of defects in extrusion was examined by Sukolski[10] using plasticine models. In particular, the effects of lubrication and temperature gradients were simulated using layers of Plasticine of differing hardness. The effects of convex and concave punches on the flow pattern were studied. This investigation may be criticized on the grounds that the flow on the outside of the specimen was observed through a glass panel. This could differ markedly from the centre of the specimen if friction was at all appreciable. Also, a sharp discontinuity in hardness may produce effects which differ from those obtained with a continuous gradient.

Direct Extrusion

Plane-strain direct-extrusion experiments were carried out in the apparatus shown partly dismantled in Fig. 2. The procedure was described in Part I of this paper. Except where otherwise stated the temperature was 31·0° C and the extrusion rate approximately 0·04 in./min. It is not known precisely to what extent strain hardening was important since it is impossible to evaluate a single strain rate for a complex deformation process from the extrusion rate. However, the data in Fig. 10 of Part I indicate that the effect of this factor should not be great with the smaller reductions.

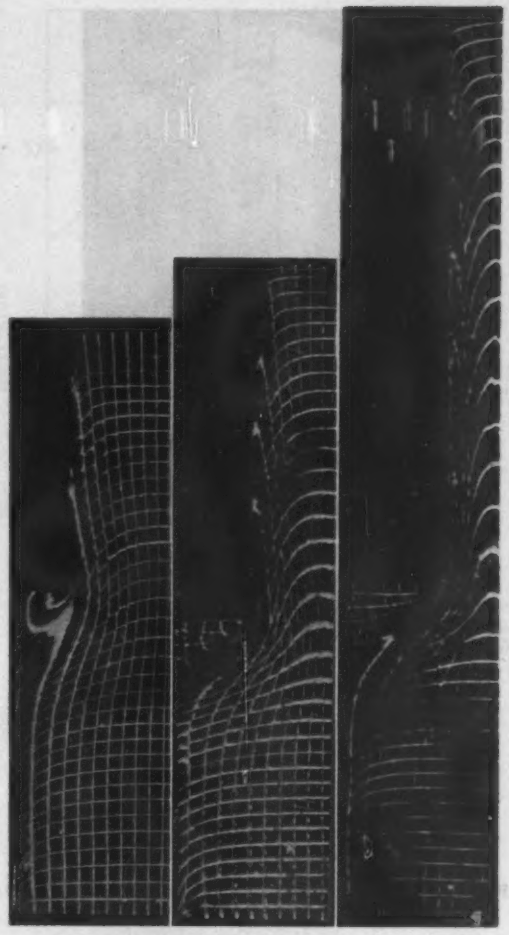
The effect of the following variables was studied:

(i) Frictional conditions
(ii) Percentage reduction



(*a*) Theory (*b*) Wax

Fig. 3—Comparison of the flow of wax in direct extrusion from a lubricated container with the theoretical behaviour (66·7% reduction). Theoretical pattern after Green



(*a*) 33·3% reduction (*b*) 50% reduction (*c*) 66·7% reduction
Only half-patterns are shown to avoid duplication

Fig. 4—The direct extrusion of wax from a rough container

(iii) Temperature
(iv) Temperature gradients.

Frictional Conditions—Typical extrusion-load curves obtained with friction coefficients of about 0·1 and 0·5 were given in Part I and it was shown that the grid pattern for wax extruded with the higher frictional condition agreed very closely with that of a lead billet extruded from the lubricated container. From this it is concluded that the yield-point phenomenon and strain hardening of the wax may be ignored in the extrusion studies.

In Fig. 3, the flow pattern for the lubricated wax billet is compared with the theoretical pattern for frictionless conditions.[6] The agreement is again good, although the upward curvature of the horizontal lines in the plastic zone is less pronounced in the wax billet. From previous plane-strain deformation experiments it was known that friction could produce significant effects upon the pattern even in the well lubricated condition. A stepwise extrusion was,

Fig. 5—Surface defects found with low extrusion temperatures

therefore, performed, the apparatus being dismantled and the billet re-lubricated between each step. No significant difference could be detected in the flow, the only difference being slight discontinuities in the pattern caused by loading and unloading, and it is therefore assumed that with suitable choice of lubricant a close approach to the ideal, friction-free, condition can be obtained with this technique.

Percentage Reduction—The percentage reduction was varied by the use of different size die plates at the end of the extrusion container. Extrusion under rough and lubricated conditions was investigated at 33·3%, 50%, and 66·6% reduction at 31° C. The patterns obtained in the rough condition are shown in Fig. 4. They display the usual features of direct extrusion patterns, viz. an increase in the size of the dead-metal zone with increasing reduction, resulting in an increasing degree of inhomogeneous deformation in the extruded portion as shown by increasing curvature of the transverse grid lines. The grid patterns shown here and in subsequent illustrations are included only as evidence of deformation and not for analysis. The values of extrusion load are discussed below.

Temperature—Extrusion from a rough container with 66·6% reduction was carried out at several temperatures to find out whether a change in yield stress had any effect on the flow pattern. Two effects were observed below 28° C: (*a*) the pattern became distorted due to cracking along the grooves of the grid; (*b*) surface cracking was seen in the extruded portion. An example of the latter defect is shown in Fig. 5. This behaviour is sometimes found in industrial extrusions when the metal lacks ductility. Apart from the effects of cracking, no changes in the flow pattern were observed.

Temperature Gradients—There are often considerable temperature gradients across the billet in industrial practice. Indeed, the container is sometimes heated by allowing the hot billet to remain there for a time before extrusion, the general practice, however, is to have a supplementary gas or electric heater. Nevertheless, the temperature difference is usually large. Thus, as the extrusion proceeds, a thermal gradient will develop across the billet. An opposing tendency is the generation of heat due to the frictional work and internal work of deformation done on the billet. This is only important in aluminium and its alloys, where the temperature may rise 100° C, possibly causing hot shortness, melting of eutectic phases, and improper recrystallization. It has been overcome by 'taper-heating' of the billet.[11]

It is apparent, therefore, that temperature variation is one of the factors which must be taken into account when the results of the theory of plasticity and laboratory model experiments are applied to industrial processes. The governing factor is the variation of the yield stress of the metal with temperature. For example, in the extrusion of steel a variation from 1200° C at the centre of the billet to 1100° C at the surface would cause about 30% variation in the yield stress.

Because of the temperature dependence of the yield stress of paraffin wax, it was possible to perform an experiment which simulated practical conditions closely. The extrusion container and billet were soaked at 32·5° C and were then placed in the hydraulic testing machine where extrusion was carried out at room temperature (21° C). The temperature conditions in the billet were investigated by using a reference block having similar dimensions to the billet. This block contained thermometers, which were spaced across the width of the billet at a depth of 1 in. from the die face, which is in the region of the billet undergoing deformation. The block was placed in the extrusion container and conditions were identical to those in the extrusion experiment. The variation of temperature across this section with time is shown in Fig. 6. As a result of the low thermal conductivity of wax, ($2{\cdot}5 \times 10^{-3}$ J cm/cm^2 s °C), and with the extrusion rate of 0·04 in./min, a suitable length of billet could be extruded without undue changes in the temperature distribution. The curves shown for the reference block only give a rough indication of what took place since the length of the main billet continually decreased as extrusion proceeded, but it is possible to make an estimate of the variation in yield stress using the data obtained in the experiments described in the previous section. For example,

after 30 min the yield stress at the outside would be about twice that at the centre. The flow patterns from the two experiments are shown in Fig. 7. The second of these has been photographed, since distortion and fracture along the boundary of the dead zone prevented the adoption of the normal reproduction method. The first experiment was stopped after 20 min and the second after 30 min, when there was a sudden drop in load due to the fracture. In both cases, the normal fall in load due to friction was nearly balanced by the increase due to the drop in temperature so that the load remained almost constant. The patterns show that a fixed dead-zone is not developed; the boundary between the rigid and deforming material moves continuously inwards so that the 'effective die' through which the material passes becomes progressively narrower. The deviation from the constant temperature pattern (Fig. 4*c*) is very marked, the inhomogeneity of the extruded portion being considerably increased.

Tube Extrusion

Experiments were performed on the extrusion of a tube from a square billet, since the previous tests had shown a good qualitative agreement between

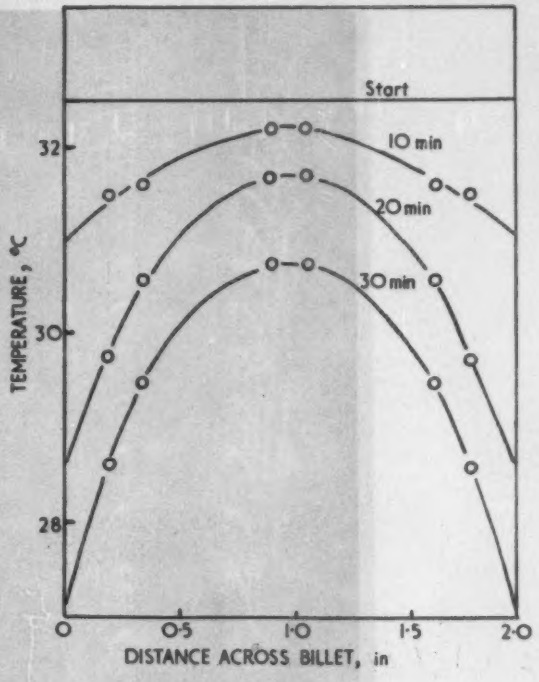
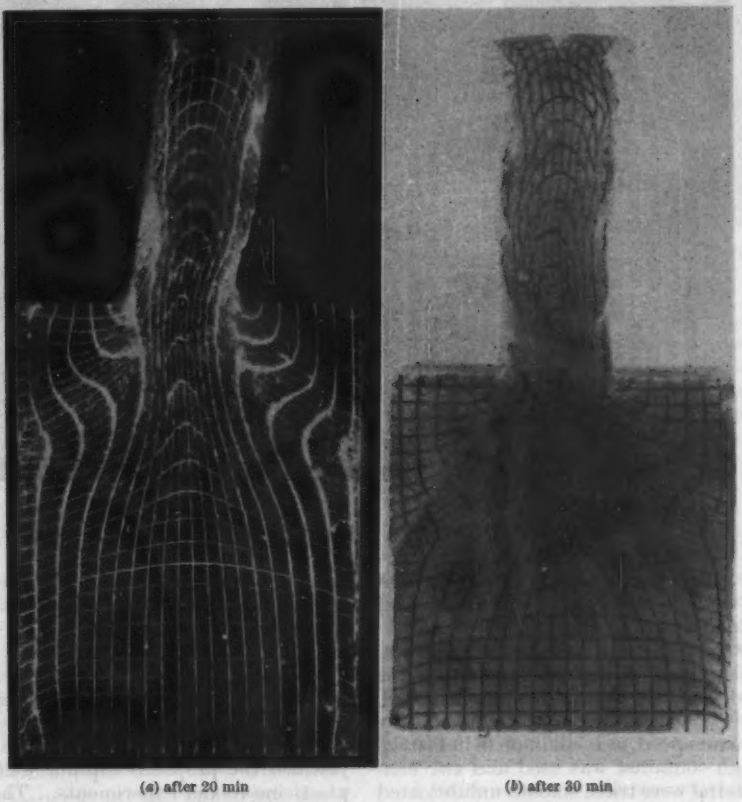
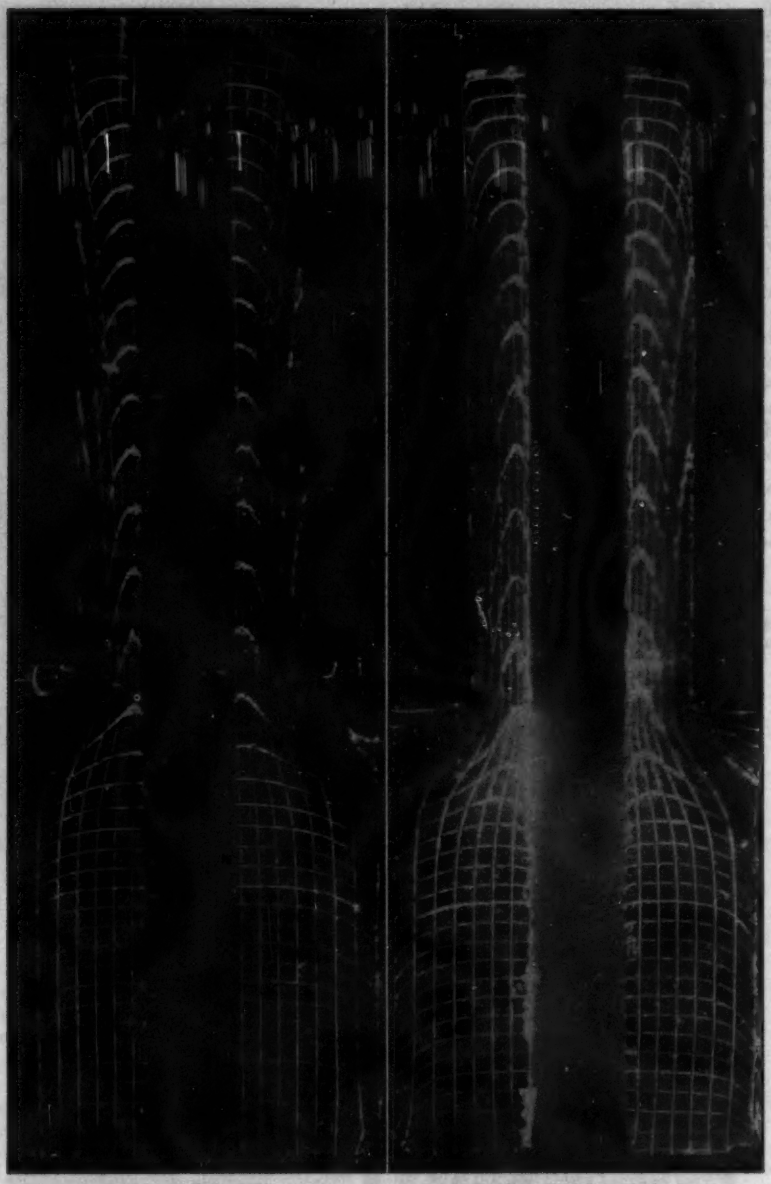


Fig. 6—Temperature gradients across the extrusion billet at a section 1 in. from die (room temperature 21·0° C)



(*a*) after 20 min (*b*) after 30 min

Fig. 7—Flow pattern from billets extruded with a temperature gradient



(a) smooth mandrel (b) roughened mandrel

Fig. 8—Flow in tube extrusion (71% reduction)

plane strain and axial symmetric conditions. A split cylindrical billet would be difficult to machine without more elaborate equipment.

Experiments were performed in which a 1½-in. dia. tube was extruded over a ½-in. dia. mandrel, the billet being first drilled to accommodate the mandrel. The latter was attached to the punch so that they advanced at the same speed, as is common in industrial practice. A rough container was used and two conditions of the mandrel were tried, smooth unlubricated and roughened (knurled). The respective flow patterns are shown in Fig. 8. The effect of the increased friction on the mandrel is shown by the greater dragging-back of the material in contact with the mandrel.

It is possible to make qualitative comparison with a corresponding plane-strain experiment, which is extrusion through a non-central die. The flow in this instance has been described by Green,[7] who justified the proposed slip-line fields by results from plasticine model experiments. The pattern relevant to the present experiments is shown in Fig. 9. The

agreement with Fig. 8*b* is quite good. (Fig. 9 shows a reduction of 67% whilst the equivalent plane strain reduction to Fig. 8*b* is 50%).

It is interesting to note that the extrusion pressure for flow over a lubricated mandrel agrees well with that for the billet extrusion considered earlier with the same area reduction, whereas with a rough mandrel, the load is slightly higher (*see* Fig. 15).

Inverted Extrusion

It is commonly accepted that flow in the lubricated direct extrusion process is similar to that for inverted extrusien. This has largely arisen owing to the similarity in extrusion pressures for the two processes. Comparatively little experimental work has been done to establish the flow pattern for the inverted process.

By a theoretical approach, Hill[4] has derived three slip-line fields for inverted extrusion, assuming no friction on the container walls, these fields holding for less than 50%, 50%, and greater than 50% reduction. In all three cases a dead-metal zone bounded by a slip line meeting the container wall and die aperture at 45° was postulated. So far as the authors are aware, no experimental confirmation of these fields has been obtained. Purchase and Tupper interpreted the flow patterns from their lubricated direct-extrusion experiments with lead[5] as those which would be expected from Hill's pattern for inverted extrusion. However, Johnson,[12] from considerations of extrusion pressures, suggested that the lubrication conditions were far from ideal. Indeed, the patterns are in agreement with those which would be expected for conditions of direct extrusion with partial lubrication.

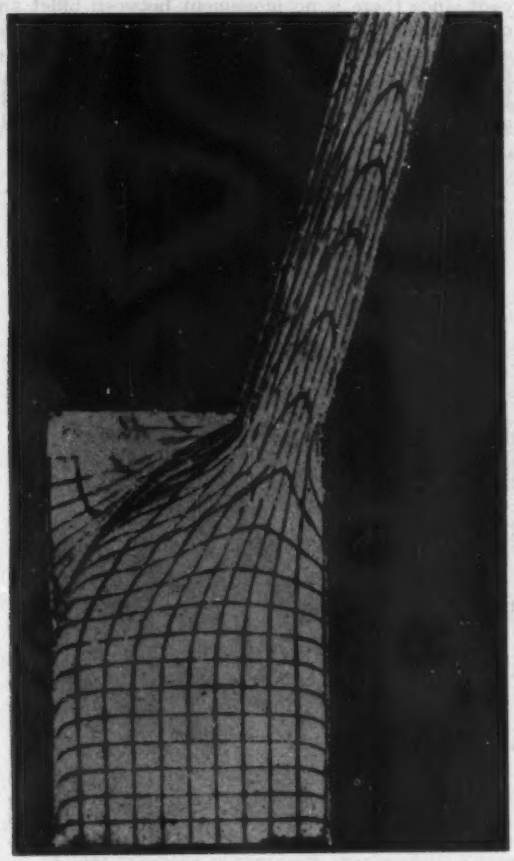


Fig. 9—Flow of Plasticine in unsymmetrical plane-strain extrusion (after Green)

Fig. 10—Flow of wax in inverted extrusion with lubricated die and container (60% reduction)

No evidence for the existence of a dead-metal zone could be obtained from any of the direct extrusion experiments with lubricated die and container referred to earlier. This is in agreement with the Plasticine model experiments conducted by Green.[6] Hence it was thought worthwhile to study the inverted process with particular reference to frictional conditions. Since fairly good agreement was obtained between the theoretical and actual patterns in direct extrusion, it was considered that the technique could be used to establish the flow conditions in inverted extrusion.

A series of wax blocks was extruded by the inverse method at 31° C under conditions of plane strain

Fig. 11—Flow of wax in inverted extrusion with rough die and container (63% reduction)

with various reductions in the range 25–75%. Considerable difficulty was experienced in preventing the leakage of wax between the die and container wall and the patterns reproduced later are for extruded billets in which the side leakage was observed to be of negligible proportions.

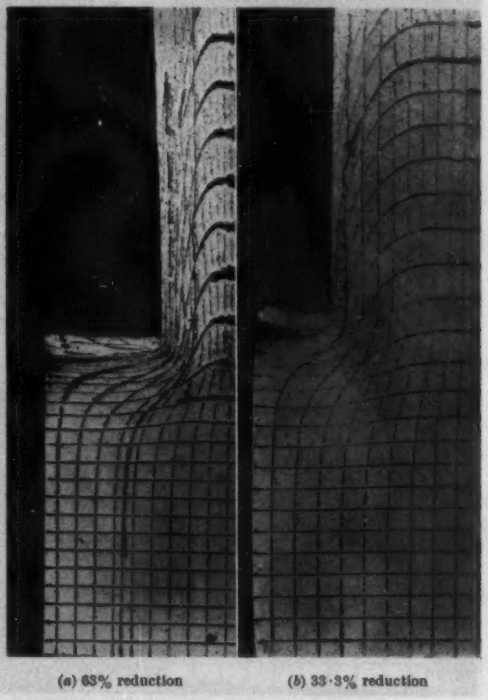
Various combinations of die and wall friction were investigated. With a lubricated die and container, the flow pattern at all reductions was identical with that for direct extrusion under the same conditions; i.e. no dead-zone formation could be detected. A typical pattern at 60% reduction is shown in Fig. 10. The grid line adjacent to the surface of the billet at all reductions studied was continuous into the corner of the container and then flowed across the die surface into the extruded portion.

A flow pattern for extrusion with high frictional conditions is reproduced in Fig. 11, the die and container walls in this case being lined with coarse emery paper. No significant difference from the preceding case is observed and once again no dead-metal zone is found.

In a third series of experiments the container walls were lubricated but the die surface was roughened by knurling to produce a higher coefficient of friction than that obtained with emery paper. Patterns obtained in this way are shown in Fig. 12 and it is noticeable that a restricted dead zone has formed adjacent to the die plate. The size of the zone is smaller than that assumed in Hill's theoretical treatment.

In order to check whether the formation of this zone was due to increased friction on the die face or reduced friction at the container wall a test was carried out using a knurled die face and the container walls lined with emery paper. The results gave no evidence of the existence of a dead zone, which suggests that such a zone is only produced when high friction at the die face is combined with low friction along the container walls. The reduced size of the dead zone is thought to be due to inadequate lubrication at the container walls.

In the ideal case, friction on the walls is not significant since there is no movement between billet and container. However, the initial elastic distortion of a real material will possibly control the formation of the dead zone. Once the zone has formed, it must be displaced continuously along the wall by the advancing die. This is probably the reason why the



(*a*) 63% reduction (*b*) 33·3% reduction

Fig. 12—Flow of wax in inverted extrusion with rough die and lubricated container

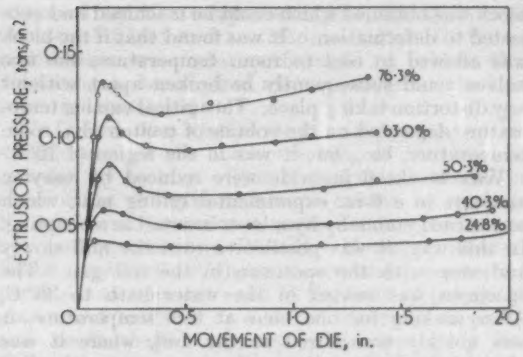


Fig. 13—Inverted extrusion-pressure curves for reductions between 24·8% and 76·3%

the zone is only maintained with lubrication of the walls coupled with a rough die surface.

Extrusion-pressure Curves

Typical inverted extrusion-pressure curves obtained at various reductions are shown in Fig. 13. The extent of the fall in load following the initial peak diminishes with decreasing reduction. It would be expected that the curves would remain horizontal since the extrusions were discontinued before end effects became apparent. It is noticeable, however, that in each case, the extrusion load increases slowly as the die advances. This is attributed to leakage of material between the die plate and the container walls. The slope of the curve increases with increasing reduction since the area of this material, relative

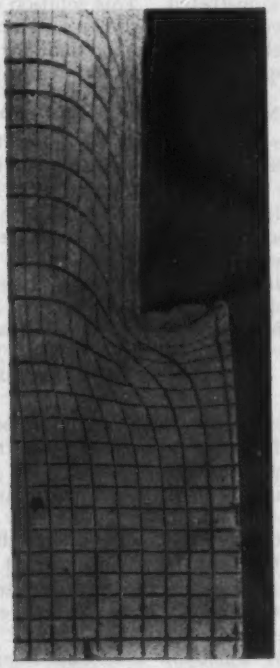


Fig. 14—Modification of the dead-zone resulting from leakage past the die

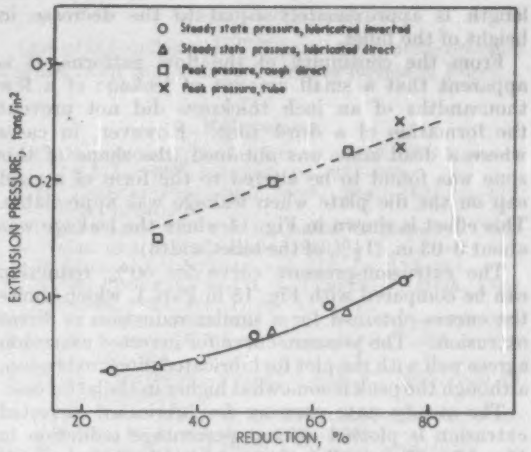


Fig. 15—Variation of extrusion pressure with percentage reduction

to the area of the extruded portion, becomes significantly greater. It is interesting to note that the leakage material is apparently not extruded, i.e. its

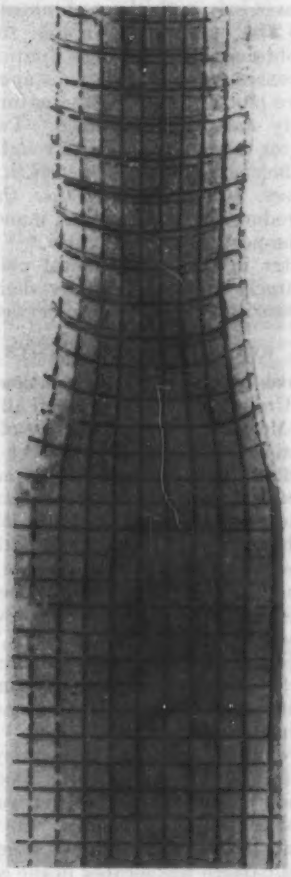


Fig. 16—The flow of wax in rolling (33% reduction)

length is approximately equal to the decrease in height of the billet.

From the continuity of the flow patterns, it is apparent that a small amount of leakage of a few thousandths of an inch thickness did not prevent the formation of a dead zone. However, in cases where a dead zone was obtained, the shape of this zone was found to be altered to the form of a rigid cap on the die plate when leakage was appreciable. This effect is shown in Fig. 14 where the leakage was about 0·03 in. (1½% of the billet width).

The extrusion-pressure curve for 50% reduction can be compared with Fig. 15 in Part I, which shows the curves obtained for a similar reduction in direct extrusion. The pressure curve for inverted extrusion agrees well with the plot for lubricated direct extrusion, although the peak is somewhat higher in the latter case.

The steady-state pressure for lubricated inverted extrusion is plotted against percentage reduction in Fig. 15. The steady-state pressure is taken as the minimum in the curve following yielding. Within the limits of experimental error, the points for all the friction conditions studied in the inverted process are fitted by the same curve.

The steady-state pressures for lubricated direct extrusion are also shown on this diagram and their values agree closely with those obtained for inverted extrusion. The upper curve in Fig. 15 records the pressures obtained with a high friction coefficient in direct extrusion. In this instance the peak pressures are plotted, since by the nature of the process a steady state is not attained. Two points are also shown for tube extrusion with rough and smooth mandrels, the container being lined with emery paper in both cases. It is apparent that the additional friction introduced by a roughened mandrel has only increased the peak pressure slightly.

The scatter in the experimental points in these curves is largely accounted for by slight variations in temperature and extrusion rate between tests.

ROLLING EXPERIMENTS

There have been many investigations of flow in rolling and Underwood[13] has reviewed all the methods critically. Most of the experimental studies have been by observation of the deformation of networks of lines scribed on the surface of the specimen, but such markings cannot be considered in terms of plane strain in the presence of non-uniform lateral spread. Studies with marker plugs yield only limited information. Experiments have also been made with layered plasticine models.[14, 15] A plasticine experiment could be conducted in which a grid pattern was marked on the centre section of a composite block, but in view of the necessary adhesion between the two halves of the block to avoid separation during rolling, it would be difficult to part the two halves after deformation without distortion of the grid.

The following technique was, therefore, developed for the production of a suitable wax block. A block was machined on one side and a grid was scribed on in the usual manner. This block was placed in a container and molten wax was cast alongside it such that the grid pattern was located in the central plane. If the casting temperature was correct a composite block was obtained which could be machined and subjected to deformation. It was found that if the block was allowed to cool to room temperature, the two halves could subsequently be broken apart without any distortion taking place. The critical casting temperature depended on the volume of molten wax, room temperature, etc., but it was in the region of 70° C.

Wax blocks 6 in. wide were reduced by varying amounts in a 6-in. experimental rolling mill, which was turned manually by a lever inserted in a coupling. In this way, it was possible to turn the mill slowly and stop with the specimen in the roll gap. The specimen was heated in the water bath to 36° C. After soaking for one hour at this temperature, it was quickly transferred to the mill, where it was placed between two pieces of emery paper and rolled for about one half of its length. The rolls were then lifted by the screw-down mechanism and the specimen was withdrawn. The purpose of the emery paper, which had its rough side towards the wax, was to increase friction on the rolls and so simulate hot-rolling conditions. Slip between the back of the paper and the rolls was not significant, provided that it was equal on each roll, but it limited the reduction which could be obtained. A typical pattern is shown in Fig. 16. It shows similar features to Orowan's plasticine experiments, particularly the distortion of the vertical lines as they enter the roll gap, indicating the boundaries of the plastic zones and the inhomogeneity of deformation. There is appreciable recovery, as shown by the increase in thickness of the strip after rolling.

Alexander[16] has recently published a slip-line field for the hot rolling process, the validity of which has yet to be demonstrated. This solution could not be checked experimentally with the mill available, since the stock thickness would be too small for examination for the appropriate arc of contact/strip-thickness ratio.

SUMMARY AND CONCLUSIONS

The above experiments have shown that paraffin wax is a useful model material for the investigation of metal flow in deformation processes. In particular it has the following advantages:

(1) It is easy to machine to accurate dimensions, and may be deformed at a suitable temperature to simulate any required ductility. It is then cooled to room temperature, where it is rigid and may be handled without fear of further deformation.

(2) It is a cheap and rapid method for studying the patterns of deformed grids which may be simply recorded.

(3) Deforming loads may be measured and correlated with the deformation flow patterns.

(4) The deforming loads are of such a magnitude that simple apparatus may be used to give significant results.

(5) The nature of paraffin wax is such that the coefficient of friction can be maintained at a very low value. However, a wide range of frictional conditions can be investigated by the selection of a suitable surface on the deforming tool.

(6) Whereas Plasticine conforms more closely to the idealized rigid–plastic material, the behaviour of paraffin wax is closer to that of a real metal. This is

instanced by the comparison given for the direct extrusion of lead and wax shown in Part I. Other experiments were also performed, on which this conclusion is based, but are not described in this paper to conserve space.

(7) Deformation studies may be supplemented by examination of the microstructure of the wax as revealed by etching. This is particularly useful in cases where the grid technique cannot be applied. No additional information on the etching technique has been presented in Part II. However, Rhodes, Mason, and Sutton[17] have shown that commercial paraffin wax does not exist in the form of polygonal grains, but solidifies as a mixed structure of plate- and needle-shaped crystals. This apparently explains the structures observed and illustrated in Part I.

Experiments have been performed on direct and inverted extrusion under various frictional conditions. Close agreement between the flow patterns and extrusion-load curves for the two processes was only found when the friction was low. The conditions for dead-zone formation in inverted extrusion have been investigated, and it would appear that this only occurs under specific frictional conditions at the die and container surface.

A technique has been developed for the study of flow in rolling. This technique could be used to study other forming processes in which a split specimen cannot be used, e.g. forging and pressing.

Acknowledgment

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The Determination of Arsenic in Iron and Steel

By the B.I.S.R.A. Methods of Analysis Committee

SYNOPSIS

A colorimetric method for the routine determination of arsenic contents up to 0·03% is outlined and the development of a standard method for the determination of all arsenic contents in iron and steel is described. The latter is based on reduction and precipitation of arsenic with hypophosphite and titration with iodine. 1494

IN 1950 the Pig Iron, Carbon and Low Alloys Steels Analysis Sub-Committee* was asked to undertake the development of a standard method for the determination of arsenic in pig iron and carbon and low-alloy steels. Two procedures were examined:

(1) A method based on reduction and precipitation of elemental arsenic with hypophosphite and titration with iodine. A report of this work was given at the Sixth Chemists' Conference (see *Proceedings*, 1952, page 32).

(2) A colorimetric method, based on the 'molybdenum blue' reaction, after distillation of the arsenic as halide, and conversion to arseno-molybdate.

In 1955 the Highly Alloyed Steels and Ferro-Alloys Analysis Sub-Committee† was asked to extend the work done on the hypophosphite method with a view to its application to tungsten high-speed steels and if possible to other types of highly alloyed steel.

This report summarizes the work done by both Sub-Committees engaged on the project.

Paper MG/D/187/57 of the Metallurgy Division of the British Iron and Steel Research Association, received on 16th October, 1957.

* The constitution of the Pig Iron, Carbon and Low Alloy Steels Analysis Sub-Committee at 31st March, 1957, was: Mr. S. W. Craven (*Chairman*), I.C.I. (Alkali Division); Mr. P. E. Clary, Ford Motor Co., Ltd.; Mr. W. E. Clarke, British Cast Iron Research Association; Mr. L. J. Clements, Round Oak Steel Works Ltd.; Mr. C. B. Clyde, Lanarkshire Steel Co., Ltd.; Mr. L. E. Gardner, Edgar Allen and Co., Ltd.; Mr. R. F. Jones, Steel Company of Wales Ltd.; Mr. A. P. Lunt, Park Gate Iron and Steel Co., Ltd.; Mr. A. W. Reed, Consett Iron Co., Ltd.; Mr. P. D. Ridsdale, Bureau of Analysed Samples Ltd.; Mr. C. W. Short, John Lysaght's Scunthorpe Works Ltd.; Mr. H. J. Turner, Steel Peech and Tozer. The Sub-Committee acknowledges the assistance of the late Mr. N. D. Ridsdale throughout its work.

† The constitution of the Highly Alloyed Steels and Ferro-Alloys Analysis Sub-Committee at 31st March, 1957, was Mr. B. Bagshawe (*Chairman*), Brown-Firth Research Laboratories; Mr. C. D. Atkinson, Sheffield Testing Works Ltd.; Mr. J. W. Flint, Wm. Jessop and Sons Ltd.; Mr. L. E. Gardner, Edgar Allen and Co., Ltd.; Mr. S. Harrison, Kayser Ellison and Co., Ltd.; Mr. J. D. Hill, Bragg Laboratory, N.O.I.D.; Mr. G. M. Holmes, London and Scandinavian Metallurgical Co., Ltd.; Mr. G. Murray, Brown Bayley Steels Ltd.; Mr. R. T. Postlethwaite, Samuel Fox and Co., Ltd.; Mr. L. N. Taylor, Samuel Osborn and Co., Ltd.; Mr. J. L. West, Hadfields Ltd.; Mr. W. Wright, Permanent Magnet Association.

Table I

SUMMARY OF RESULTS OBTAINED USING COLORIMETRIC METHOD

(APPENDIX I)

	Arsenic, %			
Analyst	*MGS*/179	*MGS*/219	*MGS*/297	*MGS*/298
1	0·024 0·025	0·0060 0·0050	0·0235 0·0235	0·0012
2	0·024 0·021 0·027	0·0060 0·0055 0·0065	0·0170 0·0175 0·0190	0·0010 0·0015 0·0015
3	—	—	0·0230 0·0240	0·0020 0·0020
4	0·024 0·023	0·0045 0·0045	0·0185 0·0175 0·0185	0·0005
5	0·024	0·0040	0·019 0·020	0·0005 0·0005
Average	0·024	0·005$_3$	0·020$_6$	0·001$_1$

EXPERIMENTAL

The Colorimetric Arseno-Molybdate Method

Trials were made of a method put forward by the Electrical Sheet Analysis Sub-Committee.[1] In this method the arsenic is distilled as halide from a sulphuric acid solution of the sample after reduction with a mixed potassium-bromide–hydrazine-sulphate reagent. The determination is completed by converting the arsenic to arsenomolybdic acid and determining the ' molybdenum blue ' produced by reduction with hydrazine sulphate.

Very erratic results were obtained at first, and a number of modifications were made to the procedure. Complete removal of nitric acid before distillation was found to be essential and, by substituting perchloric acid for sulphuric acid, this was achieved without any danger of mechanical loss, and the time required was considerably reduced. Satisfactory recovery of arsenic was obtained under these conditions, provided that the capacity of the distillation flask did not exceed 150 ml and that the neck of the flask, the splash head, and the delivery tube were either lagged with asbestos string or heated to about 110° C.

Attention was next directed to the development of the ' molybdenum blue ' colour, and here it was found that the colour intensity was critically dependent on the relative concentrations of molybdate, acid, and hydrazine sulphate. It is therefore essential that the addition of the optimum amounts of reagents recommended in the final method should be strictly adhered to, both in the preparation of the calibration curve and in the actual determination. If this is not done, blanks are erratic and colour development is variable.

The Sub-Committee concluded that the application of the colorimetric procedure is limited to steels containing less than 0·03% arsenic. Within this limit, however, it can be a useful method, provided that strict attention is paid to standardization of the conditions. It was considered that the procedure could not be recommended for use as a British Standard method.

Details of the method as finally used by the Sub-Committee and a diagram of the apparatus specified are given in Appendix I, and representative results obtained on a series of steels are given in Table I. The type composition of these steels is shown in Table II.

The Hypophosphite Method

The work done by the Pig Iron, Carbon and Low Alloy Steels Analysis Sub-Committee was based on the method published by Evans.[2, 3] Various changes of operational detail were made and satisfactory results were finally obtained using the modified method described in Appendix II. The performance of the method is shown by the results in Table III obtained on a selection of pig irons and carbon and low-alloy steels, as shown in Table IV.

Preliminary work carried out by the Highly Alloyed Steels and Ferro-Alloys Analysis Sub-Committee, with a view to extending the scope of the method, indicated serious interference from chromium, in excess of about 4%, due to precipitation of basic chromium sulphate which occluded arsenic. There was also interference from tungsten, molybdenum, and vanadium which produced blue reduction compounds with the hypophosphite. In addition, heavy deposition of salts occurred after hypophosphite reduction when phosphoric acid was used to form a complex with tungsten. This interfered seriously with the filtration of the precipitated arsenic and in such cases the results obtained were very inconsistent. Attempts to avoid the use of phosphoric acid, by precipitation and removal of tungsten as a hydrolysis product, were unsuccessful, owing to occlusion of arsenic in the precipitate.

Low results were sometimes obtained on carbon steels, for which the method had previously been found satisfactory, and this was attributed to partial volatilization of arsenic during the hypophosphite boiling period, as arsenic stains were detected in the air condensers. This was eventually overcome by modifying the hypophosphite reduction, giving one boiling period only of 15 min instead of the two periods of 15 and 30 min with an intermediate addition of hypophosphite. A permanganate oxidation treatment was introduced, before the hypophosphite reduction, to ensure complete destruction of carbonaceous matter, and the addition of 3 ml hydrofluoric acid was omitted because of high and variable blanks caused by release of arsenic from the glassware.

These changes led to much improved performance, but there was still interference from basic chromium

Table II

APPROXIMATE COMPOSITION OF SAMPLES *MGS*/179, 219, 297, AND 298,%

Sample	C	Mn	Si	Ni	Cr	Mo	Others	Type
MGS/179	0·31	0·56	0·23	3·0	0·9	0·50		3% Ni–Cr–Mo steel
MGS/219	0·008	<0·005	0·002	0·01	0·001			Pure iron
MGS/297	0·019	0·025	0·025	0·03	0·014	0·01	Cu 0·08 W 0·05 Al 0·05 V 0·01	Pure iron
MGS/298	0·016	0·001	0·004				Al 0·02	Pure iron

Table III

SUMMARY OF RESULTS ON A SERIES OF PIG IRONS AND CARBON AND LOW-ALLOY STEEL SAMPLES USING APPENDIX II

Analyst	Arsenic, %—Sample *MGS*/					
	128	161*A*	162*A*	163	178	179
1	0·039	0·22	0·051	0·055	0·031	0·024
2	0·038	—	—	0·057	0·030	0·024
3	—	0·22	0·053	0·058	0·031	0·025
4	0·039	0·24	0·051	0·055	0·032	0·022
5	0·039	—	—	0·056	0·029	0·022
6	0·039	0·24	0·051	0·058	0·031	0·024
7	0·042	0·24	0·053	0·055	0·030	0·023
8	0·038	0·22	0·050	—	0·030	—
9	—	0·23	0·049	0·055	0·031	0·022
10	0·040	0·22	0·054	0·053	0·032	0·024
11	0·039	—	0·052	0·055	0·029	0·024
Average	0·039	0·23	0·052	0·056	0·030	0·023
Range	0·038 –0·042	0·22 –0·24	0·049 –0·054	0·053 –0·058	0·029 –0·032	0·022 –0·025

salts produced during fuming, from reduction compounds of tungsten, molybdenum, and vanadium, and from salt deposition at the hypophosphite reduction stage when phosphoric acid was used.

Further work showed that a minimum phosphoric acid concentration of 20% by volume was essential to ensure the complete conversion of tungsten, molybdenum, and vanadium to non-reducible complexes. As the hypophosphite reduction was done in a volume of 200 ml, the minimum requirement of phosphoric acid was 40 ml. Using this increased amount of phosphoric acid it was found that the method could be simplified and the formation of basic chromium salts completely avoided by evaporating the sample solution to incipient fumes only. Nitric acid is completely expelled from the hot acid concentrate (40 ml phosphoric acid + 15 ml sulphuric acid) and, if fuming is avoided, dilution with water gives a clear extract containing only precipitated silica. Furthermore, if a few drops of hydrofluoric acid are added subsequently, there is no need to filter the solution before the hypophosphite reduction.

It was considered that the hydrochloric acid concentration (50% v/v) previously used was too high when phosphoric acid was also present and it was confirmed experimentally that this was one of the main factors governing the precipitation of salts, phosphates and/or sodium chloride, on cooling after hypophosphite reduction. It appeared that the relevant condition for arsenic precipitation was the total acidity, and so when phosphoric acid is used the hydrochloric concentration should be reduced correspondingly. Tests were made at varying acidities and the following observations were noted:

All tests in volume of 200 *ml containing* 40 *ml* H_3PO_4 *sp.gr.* 1·75)

HCl present, ml of sp. gr. 1·16–1·18 acid	Equiv. Acidity, % v/v	
100	50	Blue reduction colour; salts deposited
80	40	Blue reduction colour; no salts deposited
60	30	No colour; no salts deposited
40	20	No colour; no salts deposited

Determinations of arsenic were made on *MGS*/186 (18% tungsten steel) using the 30% and 40% hydrochloric acid concentrations, and in each case 0·024% arsenic was found. No blue reduction compounds were formed, and there were no deposited salts and no filtration difficulties. The 30% hydrochloric acid concentration was adopted in the subsequent work, as this was shown to provide a wider margin of certainty in avoiding the difficulties previously noted, e.g. the heavy deposition of salts.

It was not clear whether the potassium permanganate treatment introduced to ensure the destruction

Table IV

SAMPLES USED IN TESTS OF METHOD OF APPENDIX II

Sample No.	Type
MGS/128	2% chromium, 2% tungsten steel
MGS/161*A*	Pig iron
MGS/162*A*	Pig iron
MGS/163	Leaded carbon steel
MGS/178	3% chromium steel
MGS/179	*see* Table II

Table V

DETERMINATION OF ARSENIC IN HIGH-CARBON SAMPLES

	Analyst No.	Arsenic, %	
		With $KMnO_4$	Without $KMnO_4$
No. 1 (hematite iron)	2	0·026, 0·028	0·027, 0·030
	6	0·027	0·025
	9	0·030, 0·028	0·029
No. 2 (white iron)	2	0·010, 0·011	0·006, 0·008
	6	0·010	0·010
	9	0·013, 0·012	0·010
No. 3 (2%C, 14% Cr)	2	0·015, 0·016	0·012
	6	0·013	0·013
	9	0·015, 0·015	0·015

Table VI

DETERMINATION OF ARSENIC IN A SERIES OF IRON AND STEEL SAMPLES USING THE RECOMMENDED METHOD (APPENDIX III)

Analyst	Arsenic, %					
	MGS/148	*MGS*/186	*MGS*/236	*MGS*/289	*MGS*/290	*MGS*/293
1	0·021	0·025	0·018	0·064	0·086	0·021
2	0·021	0·025	0·015	0·066	0·085	0·022
3	0·020	0·022	0·015	0·061	0·086	0·020
4	0·022	0·024	0·018	0·065	0·086	0·022
5	0·021	0·021	0·014	0·060	0·086	0·024
6	0·020	0·024	0·018	0·066	0·087	0·022
7	0·020	0·020	0·015	0·062	0·082	
8	0·022	0·024	0·016	0·064	0·085	0·025
9	0·020	0·023	0·016	0·066	0·086	0·024
10	0·021	0·024	0·016	0·060	0·081	0·023
11	0·021	0·024	0·017	0·062	0·084	0·024
12	0·020	0·025	0·016	0·064	0·082	0·024
Average	0·021	0·023	0·016	0·063	0·085	0·023
Range	0·020–0·022	0·020–0·025	0·014–0·018	0·060–0·066	0·081–0·087	0·020–0·025

Table VII

APPROXIMATE PERCENTAGE COMPOSITION OF SAMPLES *MGS*/148, 186, 236, 289, 290, and 293

Sample No. *MGS*	Composition, %								
	Mn	Si	Ni	Cr	V	W	Co	Others	Type
148	0·24	0·6	11·2				23·7	Cu 5·1 Al 6·9	B.C.S. 233
186			0·03	3·9	1·2	18·4			18/4/1 high-speed steel
236			13·5	13·5		2·5	10·0	Mo 1·5, Nb and Ta 3·0	G18B
289								P 0·03	High-arsenic carbon steel
								P 0·02	High-arsenic carbon steel
293			8·0	18·0				Mo 2·2	Stainless steel

of carbonaceous matter was really necessary, and to test this point a panel of the Sub-Committee members made comparative tests, with and without permanganate, on two samples of cast iron and a high-carbon chromium steel. The results are given in Table V. Whilst the results do not show any marked difference, it was thought that the use of permanganate would ensure the oxidation of any residual carbonaceous matter which would be incompletely decomposed when high-carbon materials are dissolved in phosphoric acid mixtures. In several tests, particularly on the No. 2 iron, the solutions remained a dark brown in the untreated tests whilst the permanganate-treated tests were oxidized to a clear green colour. This occurrence coincided with the low results obtained by one member on two of the samples. It was therefore decided to retain the permanganate treatment.

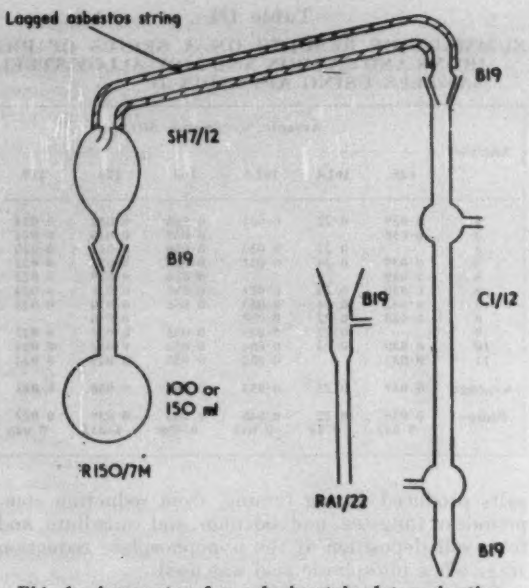

Fig. 1—Apparatus for colorimetric determination

The method was drafted in the final form and is as described in Appendix III.

Results with Recommended Method

Results obtained using the recommended method (Appendix III) on a representative selection of steels are included in Table VI. The approximate compositions of the samples used in this examination are shown in Table VII.

Results of analysis of a pure iron to which small additions of arsenic were made, either as sodium

Table VIII

TESTS SHOWING RELIABILITY OF RECOMMENDED METHOD (APPENDIX III) IN DETERMINING TRACE AMOUNTS OF ARSENIC

Analyst 2		Analyst 9		Analyst 6	
MGS/298	nil 0·001		0·001		nil 0·001
Other Steels No. 1199 3% Ni Std.	0·033	S.F. Std. (0·038)	0·038 0·038		
	Found		*Found*		*Found*
4·75g MGS/298 + 0·25g No. 1199 } equiv. 0·001$_5$	0·001$_5$	4·75g MGS/298 + 0·25g SF } equiv. 0·002$_5$	0·003	5g MGS/298 } equiv. (a) + 0·002%As } 0·002 (b)	0·002 0·002
4·5g MGS/298 + 0·5g No. 1199 } equiv. 0·003	0·003	4·5g MGS/298 + 0·5g SF } equiv. 0·004	0·006	5g MGS/298 } equiv. + 0·004%As } 0·004 (b)	0·005
4·0g MGS/298 + 1·0g No. 1199 } equiv. 0·007	0·007	4·0g MGS/298 + 1·0g SF } equiv. 0·008	0·007	5g MGS/298 } equiv. (a) + 0·005%As } 0·005	0·005
3·5g MGS/298 + 1·5g No. 1199 } equiv. 0·010	0·008	3·5 MGS/298 + 1·5g SF } equiv. 0·012	0·013	5g MGS/298 } equiv. + 0·006%As } 0·006 (b)	0·007
3·0g MGS/298 + 2·0g No. 1199 } equiv. 0·013	0·011$_5$	5g MGS/298 + 0·002%As } equiv. 0·002	0·003	5g MGS/298 } equiv. (a) + 0·010%As } 0·010	0·012
		5g MGS/298 + 0·006%As } equiv. 0·006	0·006	5g MGS/298 } equiv. (a) + 0·015%As } 0·015	0·017
		5g MGS/298 + 0·010%As } equiv. 0·010	0·010		
Blank correction % As equiv. on 5g sample basis	0·002		0·001	series (a) series (b)	0·003 0·005

arsenite or by means of a steel of known arsenic content, are given in Table VIII. These results confirm the reliability of the method for recovering arsenic when only traces, of the order of 0·002% or more, are present.

CONCLUSION

The method developed as a result of this investigation, which is described in Appendix III, has been found satisfactory for the determination of arsenic in a wide range of iron and steel samples, including tungsten high-speed steels, magnet alloys, and high-chromium and heat-resisting steels.

The method has been submitted to the British Standards Institution with a view to its acceptance as an approved British Standard.

References

1. Restricted B.I.S.R.A. Report No. MG/H/120/56.
2. B. S. Evans: *Analyst*, 1929, vol. 54, pp. 523–535.
3. B. S. Evans: *Ibid.*, 1932, vol. 57, pp. 492–494.

APPENDIX I

Determination of Arsenic—Colorimetric Method

Range

Up to 0·030% arsenic.

Reagents Required

Distilled water shall be used throughout the procedure and all reagents shall be of the highest purity obtainable.

Nitric acid: 40% v/v.

Perchloric acid: Sp.gr. 1·54.

Hydrochloric acid: Sp.gr. 1·16–1·18.

Ammonium molybdate: Dissolve 1·0 g of ammonium molybdate in 50 ml of sulphuric acid (25% v/v) and dilute to 100 ml with water.

Hydrazine sulphate: Dissolve 0·15 g of hydrazine sulphate in water. Dilute to 1 litre with water.

Molybdate–hydrazine reagent: Immediately before using, add 10 ml of the ammonium molybdate reagent and 10 ml of the hydrazine sulphate reagent to 70 ml of water. Dilute to 100 ml with water.

Apparatus (See Fig. 1)

100 ml squat Pyrex beaker with Pyrex cover.

Liebig condenser; socket and cone *B*.19.

Splash head; cones *B*.19.

Straight-delivery adaptor; socket *B*.19.

Flask R.B.; socket *B*.19; 150 ml capacity. (Splash head, delivery tube, and neck of flask should be lagged with asbestos string, or heated with electrothermal tape to 110° C.)

1-in. dia. Pyrex test tube marked at 10 ml and 30 ml.

Copper water bath with tray.

Electric air bath—thermostatically controlled.

Procedure

Weigh 0·25 g sample into a 100-ml beaker and dissolve in 10 ml of nitric acid (40% v/v). Add 8·0 ml of perchloric acid (sp.gr. 1·54) and evaporate to fumes. Continue fuming for 2 min. Cool, add 10 ml of water, and heat to dissolve salts. Transfer the solution to the 150-ml distillation flask using 20 ml of hydrochloric acid (sp.gr. 1·16–1·18) to wash out the beaker. Add 1·0 g of potassium bromide and 0·3 g of hydrazine sulphate and connect to apparatus. Heat the flask, protected by a gauze, by means of a Bunsen burner so that rapid boiling is maintained. Collect 20 ml of distillate in 10 ml of water contained in 1-in. test tube placed in a beaker of ice. Disconnect the condenser, and rinse with water. Disconnect the straight-delivery adaptor, rinse the adaptor with 10 ml nitric acid, and then with water, using as small a volume as possible. Collect all the washings in a 100-ml squat beaker. Transfer the distillate to the same beaker, washing out the test tube with water. Evaporate almost to dryness on a hot plate (*Note 1*) (solution becomes colourless) and finally to dryness in a bath of boiling water. Heat at 130° C for 30 min in an air oven. Cool, add 25 ml of hydrazine-sulphate–ammonium-molybdate reagent, cover the beaker with a cover glass, and heat in a bath of boiling water for 20 min.

Cool the solution, transfer to a 25-ml graduated flask, rinsing the beaker with the hydrazine-sulphate–ammonium-molybdate reagent. Not more than 2–3 ml should be necessary if the heating operation has been performed correctly.

Determine the optical density of the solution on an absorptiometer using 2·0-cm cells and Ilford 607 filters at a wavelength of 605 mμ, or using a spectrophotometer at a wavelength of 830 mμ with a 1-cm cell for arsenic contents less than 0·03%.

Determine a blank on the reagents by applying the entire procedure as outlined above.

Calibration

(*A*) Dissolve 0·132 g of arsenic trioxide in 2·0 ml of N sodium hydroxide, dilute with water, neutralize with sulphuric acid, add 4 g of sodium bicarbonate, and dilute to 500 ml.

Pipette 25 ml of the above and dilute to 1 litre.

1 ml = 0·002% arsenic on 0·25 g sample.
= 0·005 mg arsenic.

To a series of 100-ml beakers add 10 ml of nitric acid (40% v/v) and 8·0 ml of perchloric acid (sp.gr. 1·54) and appropriate volumes of the standard arsenic solution. Prepare as outlined in the procedure and prepare a calibration graph.

Notes

(1) A radiant heater facilitates a quicker evaporation and prevents spurting.

APPENDIX II

Determination of Arsenic in Pig Iron, Carbon and Low-alloy Steels

Reagents Required

Mixed acids: To 500 ml of water, add 200 ml of hydrochloric acid (sp.gr. 1·16–1·18) and 150 ml of nitric acid sp.gr. 1·42), mix well, and cool. Add cautiously, with stirring, 150 ml of sulphuric acid (sp.gr. 1·84), cool, and dilute to 1 litre.

Hydrochloric acid (5% *v/v*)*:* Dilute 50 ml of hydrochloric acid (sp.gr. 1·16–1·18) to 1 litre.

Hydrochloric-acid–hypophosphite wash: Dilute 250 ml of hydrochloric acid (sp.gr. 1·16–1·18) to about 900 ml, add 20 g of sodium hypophosphite ($NaH_2PO_2.H_2O$) and, when dissolved, dilute to 1 litre.

Ammonium chloride (5%)*:* Dissolve 50 g of ammonium chloride in water and dilute to 1 litre.

Starch (1%)*:* Make a suspension of 1 g of starch in 10 ml of water, add 90 ml of boiling water, cool, and dilute to 100 ml.

Sodium bicarbonate (1·25%)*:* Dissolve 12·5 g of sodium bicarbonate in water, add 2 ml of starch solution and dilute to 1 litre. Titrate with N/100 iodine until the solution assumes a faint permanent blue colour.

Iodine (N/100)*:* Dissolve 1·2692 g of resublimed iodine and 10 g of potassium iodide in 25 ml of water and dilute to 1 litre.

Sodium arsenite (N/100)*:* Dissolve 0·4946 g of arsenous oxide in 50 ml of water containing 1 g of sodium hydroxide. Dilute to 200 ml, add hydrochloric acid (5% v/v) until just acid (about 8 ml), add 4 g of sodium bicarbonate, and dilute to 1 litre.

Procedure

Weigh 5 g of sample and 1 g of electrolytic copper, transfer to a 600-ml squat beaker, add 100 ml of mixed acids, and warm to obtain complete solution (*Note 1*). Add 3 ml of hydrofluoric acid and evaporate to strong fuming (*Note 2*), cool, dilute to 100 ml, and heat until solution is complete. Filter through a paper-pulp pad into a 400-ml squat beaker, and wash the pad and residue with hydrochloric acid (5% v/v). Evaporate the filtrate and washings to 75 ml and transfer to 750-ml conical flask, rinsing the beaker with 75 ml of hydrochloric acid (sp.gr. 1·16–1·18) (*Note 3*).

Add 2 g of sodium hypophosphite, warm the solution to 50° C, and add a further 10 g of sodium hypophosphite. Attach a reflux condenser (a glass tube 60 cm × 0·5 cm i.d.) to the flask and heat for 15 min at such a temperature that steam issues gently from the condenser tube. Cool, add a further 5 g of sodium hypophosphite, and continue the heating for 30 min.

Cool to room temperature, filter through a prepared paper-pulp pad (*Note* 4), and wash both flask and pad with hydrochloric-acid–hypophosphite wash solution (about 100 ml). Complete the washing of the flask and pad with ammonium chloride solution (5%).

Return the pad and residue to the flask, rinsing the funnel with about 50 ml of the sodium bicarbonate solution (1·25%). From a burette add a measured excess of iodine solution (N/100), shake to disintegrate the filter pad, and allow to stand for 5 min. Add 250 ml of sodium bicarbonate solution and titrate immediately with sodium arsenite solution (N/100) until the blue colour lightens; then add about 5 ml excess, shake, and allow to stand until the blue colour is completely discharged. Add 5 ml of starch solution (1%) and back-titrate with iodine solution (N/100), shaking vigorously after each addition, until the blue colour just re-appears.

A blank on the reagents must be carried through all stages of the procedure, concurrently with the test determination, and an appropriate correction made.

Notes

(1) In the presence of tungsten (up to 5%) add 20 ml of phosphoric acid (sp.gr. 1·75). With this addition care is necessary during fuming to avoid frothing.

(2) Strong fuming is necessary to remove nitric acid at this stage.

(3) The solution at this stage must contain at least 50% of hydrochloric acid (sp.gr. 1·16–1·18) by volume.

(4) To prepare the pulp, tear up filter paper into small pieces and shake with a mixture of 1 part of a saturated solution of bromine in hydrochloric acid (sp.gr. 1·16–1·18) and 7 parts of water. When the paper is disintegrated, heat on a steam bath for 30 min and dilute with an equal volume of water. Make the filter pad using this prepared pulp and wash well with water.

APPENDIX III

Recommended Method for the Determination of Arsenic in Iron and Steel

Principle

The sample is dissolved in a mixture of phosphoric, hydrochloric, nitric, and sulphuric acids and the solution is concentrated by evaporation, to decompose resistant carbides and expel nitric acid. The concentrate is diluted and adjusted to give an acidity of approximately 30% v/v of hydrochloric acid and 20% v/v of phosphoric acid, and arsenic is precipitated as the element by boiling under reflux with sodium hypophosphite. The precipitate is collected, washed, and dissolved in a measured excess of standard iodine, and the determination is completed by titration with standard arsenite and iodine.

Range

The method covers the range of arsenic contents found in iron and steel.

Reproducibility

In the range 0–0·1% arsenic, replicate determinations should not differ by more than ± 0·003% arsenic.

Application

The method is applicable to all types of iron and steel, including high-chromium, high-tungsten, and other special highly alloyed steels.

Apparatus

Grade *A* graduated glassware of arsenic content negligible compared with the arsenic content of the material under test shall be used throughout.

Solutions

Mixed acids: To 500 ml of water add 200 ml of phosphoric acid (sp.gr. 1·75), 100 ml of hydrochloric acid (sp.gr. 1·16–1·18), and 75 ml of nitric acid (sp.gr. 1·42). Mix and cool. Add cautiously 75 ml of sulphuric acid (sp.gr. 1·84), cool, and dilute to 1 litre.

Hydrochloric-acid–hypophosphite wash: See Appendix II.

Ammonium chloride (5% *w/v*)*:* See Appendix II.

Starch (1% *w/v*)*:* See Appendix II.

Sodium bicarbonate (1·25%)*:* See Appendix II.

Iodine (N/100)*:* See Appendix II.

Sodium arsenite (N/100)*:* See Appendix II.

Sulphurous acid: Pass sulphur dioxide gas into water until a saturated solution is obtained.

Sampling

Recommended methods of obtaining a suitable sample for the analytical procedure outlined below are described in B.S. 1837: Part 1, " Methods for the sampling of iron and steel."

Procedure

Transfer 5 g of sample and 1 g of electrolytic copper to a 600-ml squat beaker and add 200 ml of mixed acids (*Note 1*). Digest until dissolved, and then evaporate until the concentrate is just fuming (*Note 2*).

Cool extract with 100 ml of water (*Note 3*) and transfer to a 750-ml conical flask. Add 0·5 g of potassium permanganate, boil for 5 min, add 20 ml of sulphurous acid, and evaporate to about 80 ml. Add 60 ml of hydrochloric acid (sp.gr. 1·16) and dilute to about 200 ml with water.

Add 2 g of sodium hypophosphite, warm the solution to about 50° C, add 10 drops of hydrofluoric acid (*Note 4*), and shake to mix. Add a further 10 g of sodium hypophosphite, attach a reflux condenser to the flask, heat to boiling, and boil gently for 15 min. Cool to about 50° C (not less than 40° C). Filter through a prepared pulp pad (see Note 4, Appendix II) and wash both flask and pad with hydrochloric-acid–hypophosphite wash solution (about 100 ml). Finally, wash the flask and pad several times with ammonium chloride solution (5%).

Return the filter and precipitate to the flask, rinsing the funnel with about 50 ml of the sodium bicarbonate solution (1·25%). Add from a burette a measured excess of iodine solution (N/100), shake to disintegrate the filter pad, and allow to stand for 5 min. Add 250 ml of the sodium bicarbonate solution (1·25%) and titrate immediately with sodium arsenite solution (N/100) until the blue colour lightens; then add about 5 ml excess, shake, and allow to stand until the blue colour is completely discharged. Add 5 ml of starch solution (1 %) and back-titrate with iodine solution (N/100), shaking vigorously after each addition, until the blue colour just reappears.

A blank on the reagents must be carried through all stages of the procedure, concurrently with the test determination and an appropriate correction made.

Calculation

1 ml of N/100 solution = 0·15 mg of arsenic

∴ Percentage of arsenic in the sample =

$$\frac{(A - B) \times 0{\cdot}015}{C}$$

where A = volume of iodine solution (N/100)
B = volume of sodium arsenite solution (N/100)
C = weight of sample taken.

Notes

(1) Some types of high-chromium–nickel rustless steels may not dissolve readily in this mixture. For such steels, dissolve in a mixture of 15 ml of nitric acid (sp.gr. 1·42) and 40 ml of hydrochloric acid (sp.gr. 1·16–1·18). When solution is complete add 40 ml of phosphoric acid (sp.gr. 1·75) and 15 ml of sulphuric acid (sp.gr. 1·84).

(2) This is sufficient to decompose carbides, dissolve tungsten compounds, and remove nitrates. Strong fuming should be avoided as it results in the formation of insoluble basic chromium salts.

(3) If the sample contains graphite, filter and wash with hydrochloric acid (5% v/v). Collect the filtrate in a 750-ml conical flask and continue according to the second paragraph of the *Procedure*. Discard the residue.

(4) With some samples (e.g. high-silicon irons) it is permissible to increase this to 20 drops. Since most glassware contains arsenic and all glassware is attacked by hydrofluoric acid, this must be kept to a minimum.

The Dendritic Segregation of Manganese in Steel Ingots

By R. G. Ward, M.A., Ph.D.

SYNOPSIS

The degree of dendritic segregation of manganese in sub-critically annealed nickel–chromium stee ingots has been determined by means of autoradiography. Manganese is concentrated between the dendrites, and maximum and minimum concentrations of 0·49% and 0·33% Mn have been found in a nominally 0·40% Mn steel. High manganese contents are generally accompanied by high hardness, and maximum and minimum microhardness values of 243 and 161 D.P.N. have been found. These microhardness variations are not only due to manganese segregation but are also influenced by the segregation of other elements, and no close correlation exists between manganese content and microhardness. It is suggested that the degree of interdendritic segregation of other elements is approximately the same as has been found by conventional analyses of micro-segregates from forgings. 1480

Introduction

DURING THE SOLIDIFICATION of steel, the interdendritic segregation of alloying and impurity elements inevitably occurs and subsequent elongation of these segregates by mechanical working produces highly undesirable 'banded' structures. Banding contributes to the inferior transverse properties of wrought steel,[1] and also to the tendency towards cold cracking in the heat-affected zone of metal-arc welds.[2] Although the initial segregations thus exert a considerable influence on the properties of the worked material, little is known of the actual concentration variations involved. Suitable etching techniques can give qualitative information concerning the nature and degree of the segregations, but quantitative information is difficult to obtain as the normal micro-analytical methods are inadequate for the determination of these small-scale and continuously varying concentrations. In the present study, the micro-segregation of manganese in unworked nickel–chromium steel has been determined by the use of the radio-isotope Mn 56, the distribution of which was recorded by contact autoradiography.

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THE AUTORADIOGRAPHIC METHOD

The blackening of a photographic emulsion in contact with a specimen containing a radioactive isotope can be interpreted quantitatively to give the concentration of the active element at any point in the surface of the specimen. This is in turn proportional to the total concentration of active and inactive atoms of the element studied, if these are randomly mixed.

In the present investigation the radio-isotope Mn 56 was used. This emits high-energy (2·9-MeV) β-particles which are strongly penetrating, and give rise to poor resolution in autoradiographs of massive specimens. This is largely caused by the blurring of the image produced by manganese segregation in the surface by β-particles from manganese in the specimen interior, but the effect can be mitigated by the use

of specimens thinner than the half-thickness (about 0·025 cm) of 2·9-MeV β-particles in steel. The resolution is then approximately equal to the thickness. The specimens used were therefore made about 0·003 cm thick in order to obtain a resolution which was small compared with the dendritic spacing.

The radio-isotope Mn 56 was produced *in situ* by pile irradiation of suitable ingot-steel samples. Irradiation produces the active isotope from inactive manganese by the reaction:

$$\text{Mn } 55 \xrightarrow{n,\gamma} \text{Mn } 56$$

Owing to the relatively high probability of a neutron causing such a transition (cross-section = 13·2 barns), and the short half-life ($T_{\frac{1}{2}} = 2{\cdot}58$ h), a high specific activity of Mn 56 was rapidly built up in steel samples which corresponded approximately to the En 30 specification. All other elements present were activated but with the exception of nickel their specific activities were calculated to be less than 0·1% of that of manganese for the irradiation treatments given; the specific activity of the nickel induced was 2% of that of the manganese so that approximately this percentage of the blackening on the autoradiographs is due to Ni 65 and the two effects are inseparable owing to the similar decay rates of manganese and nickel ($T_{\frac{1}{2}} = 2{\cdot}58$, 2·56 h respectively). The influence of nickel is, however, small and has been neglected in the following discussion.

PREPARATION OF SPECIMENS

Samples about 0·03 cm thick and 1·5 cm across were cut from a 2-ton square-section alloy-steel ingot of the following composition:

4·0%Ni 1·4%Cr 0·1%Mo 0·40%Mn 0·35%Si 0·13%C

The ingot had been sub-critically annealed at 650° C for several hours after casting. Three specimens giving vertical sections of the ingot near the junction of the columnar and equiaxed zones were taken, and for later reference these are labelled as follows:

Specimen 1: Section in the columnar zone, parallel to the columnar crystals
Specimen 2: Section in the equiaxed zone, parallel to the columnar crystals
Specimen 3: Section in the equiaxed zone, at right-angles to the columnar crystals.

A layer of Araldite Type 1 was cured on one face of each disc and the steel–araldite pairs were then mounted in bakelite in a metallurgical mounting press; the araldite was necessary because of the tendency of the specimens to tear away from the bakelite during the subsequent grinding operations owing to the low steel–bakelite adhesion. The mounted specimens were then reduced to about 0·001 in. in thickness before final diamond polishing to produce a suitable surface for metallographic examination.

PILE IRRADIATION

By trial and error, a 15-min irradiation at a flux of 8×10^{11} neutrons/cm^2/s in an atomic pile (B.E.P.O.) at Harwell was found to produce sufficient activity in the specimens to allow autoradiographs to be made with exposure times of a few minutes. After irradiation the specimens were extremely active, largely owing to short-lived contamination, but the necessary handling for autoradiography using tongs was quite tolerable 3 h after removal from the pile. By end-window counting methods[3] the decay of the specimen activity was then found to take place with a half-life equal to that of Mn 56, thus confirming that the activity was predominantly due to radioactive manganese.

AUTORADIOGRAPHY

Trial autoradiographs were made successfully on photographic plates, special autoradiographic plates, X-ray film, and lantern plates, but no advantage was gained by the use of special fine-grained or thin emulsions owing to the limited resolving power inherent in the use of Mn 56. "Ilford Special Lantern Plate Contrasty" was therefore used in the work detailed below; this emulsion is both fast and imposes no restriction on the accuracy attainable as it has a potentially higher resolving power than that obtainable with the isotope used.

The optimum exposure time 3 h after removal from the pile was about 2 min but owing to radioactive decay the exposure had to be doubled for every half-life (2·58 h) lapse from this time. The exposures were made in a dark room and the plates were developed and fixed according to the normal photographic procedure. Three or four consecutive exposures of varying lengths were made on each plate with the specimen pressed on to the emulsion under a 100-g weight.

Enlarged plates of the autoradiographic images were made with a vertical enlarger, and prints were made from these plates. The treble photographic process has the result that dark areas on the final prints correspond to regions of high activity and therefore of high manganese content in the specimens, but a little definition is inevitably lost in each process. Examples of autoradiographs are given in Figs. 1*a*, 2*a*, and 3*a*.

PHOTOMETRY

Optical density measurements were made on the original autoradiographs using a modified Hilger microphotometer. To permit the accurate measurement of local densities, an extremely small spot of area $5{\cdot}4 \times 10^{-5}$ cm^2 was photometered, and measurements were made at 5×10^{-3} cm intervals across each autoradiograph. Adequate photometer deflections were obtained with this small aperture by increasing the wattage of the light source to 36 W, 50% above that normally used in this apparatus.

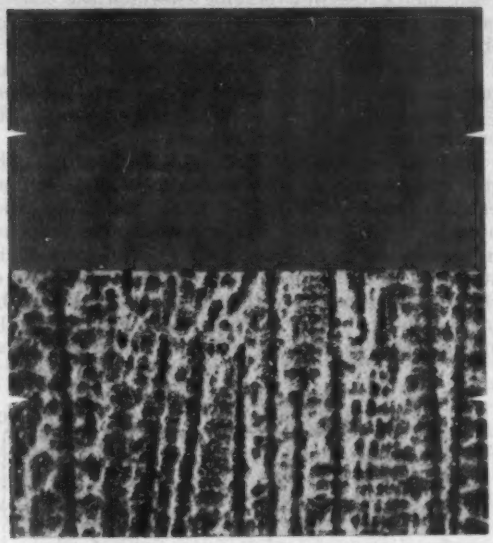
The response of the photographic emulsion to the electron emission from Mn 56 was determined for each plate used, by photometering a given region of every image on the plate. A calibration curve was then constructed for this particular plate relating the corrected optical density (defined as the logarithm of the ratio of the mean intensity of light through unexposed and exposed portions of the plate) to the exposure time. The characteristic curves for the various plates differ slightly owing to slight variations in the processing conditions of the emulsions, and a typical curve is shown in Fig. 4.

With the short exposures used, no reciprocity failure due to image fading was anticipated[4] and the optical

density can be regarded as dependent on the product of exposure time and manganese concentration. The calibration curve of optical density in terms of exposure time for constant manganese content can therefore be interpreted in terms of manganese content for constant exposure time. The manganese concentration scale is fixed by taking the mean optical density in a microphotometer traverse equal to the manganese content of the bulk sample obtained by chemical analysis. The manganese concentration scale is linear with zero manganese content corresponding to zero on the time scale, and using this concentration scale all other microphotometer readings can then be converted to manganese concentrations.

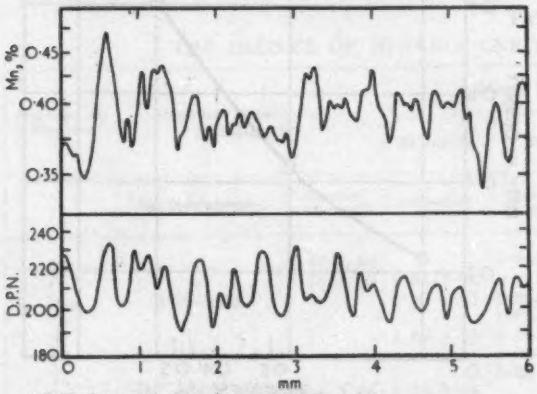
Examples of the manganese distributions obtained from microphotometer traverses are shown in Figures 1*c*, 2*c*, and 3*c*.

(*a*) Autoradiograph—manganese-rich regions appear dark.



(*b*) Photomacrograph—positively segregated regions appear light (Oberhoffer's reagent).

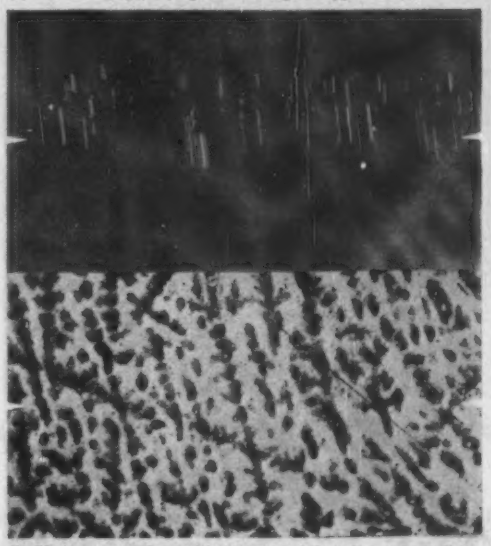
(*c*) Manganese variations along path shown on (*a*) and (*b*).



(*d*) Hardness variations along same path as (*c*).

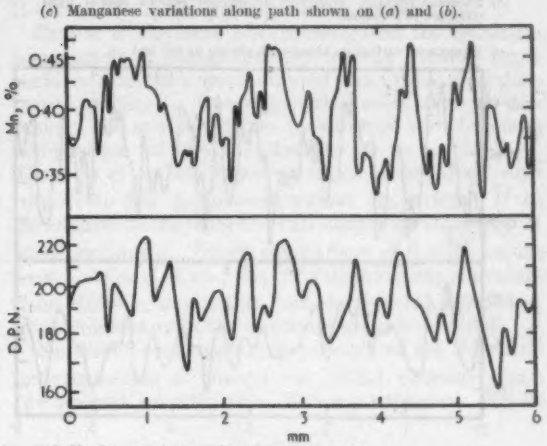
Fig. 1—Example of dendritic segregation in the columnar zone of a 2-ton ingot. Specimen 1. Vertical section parallel to the columnar crystals × 12

(*a*) Autoradiograph—manganese-rich regions appear dark.



(*b*) Photomacrograph—positively segregated regions appear light (Oberhoffer's reagent).

(*c*) Manganese variations along path shown on (*a*) and (*b*).



(*d*) Hardness variations along same path as (*c*).

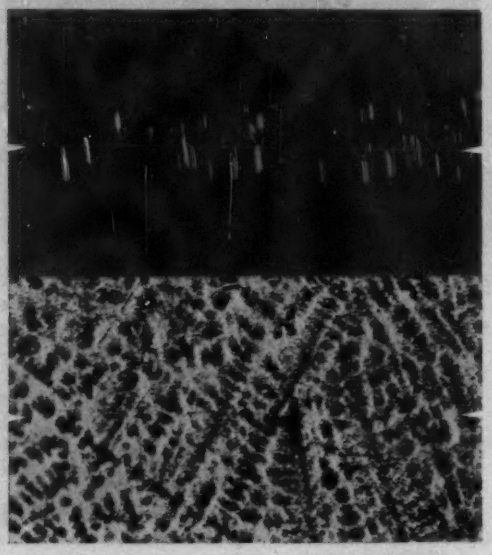
Fig. 2—Example of dendritic segregation in the equiaxed zone of a 2-ton ingot. Specimen 2. Vertical section parallel to the columnar crystals of Fig. 1 × 12

MACRO-ETCHING AND MICRO-HARDNESS MEASUREMENTS

In order to confirm that the patterns on the autoradiographs did represent the dendritic structure of the steel, the specimens were etched with Oberhoffer's reagent after autoradiography had been completed. Oberhoffer's reagent reveals the phosphorus-rich segregated regions as light areas, and agreement was found in all cases between the dendritic pattern obtained by etching and autoradiography (Figs. 1, 2, and 3).

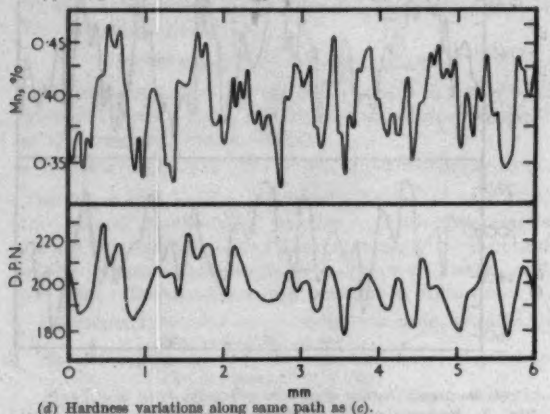
Concentration variations due to segregation undoubtedly affect the mechanical strength of the steel, and some measure of the local strength properties is desirable as similar effects may be anticipated due to banding in wrought material. Micro-hardness traverses

(*a*) Autoradiograph—manganese-rich regions appear dark.



(*b*) Photomacrograph—positively segregated regions appear light (Oberhoffer's reagent).

(*c*) Manganese variations along path shown on (*a*) and (*b*).



(*d*) Hardness variations along same path as (*c*).

Fig. 3—Example of dendritic segregation in the equiaxed zone of a 2-ton ingot. Specimen 3. Vertical section at right-angles to Fig. 2 × 12

were therefore made on the etched specimens following the photometer traverses, and examples are given in Figs. 1*d*, 2*d*, and 3*d*. Hardness indentations were made at 10^{-2} cm intervals with a load of 158 g using a Reichert micro-hardness tester, and it is estimated that the accuracy of individual Vickers pyramid hardness values is within $\pm 5\%$.

RESULTS

Comparison of the dendritic structure revealed by Oberhoffer's reagent and the autoradiographs (Figs. 1, 2, and 3) clearly shows that manganese is concentrated in the interdendritic regions. It is apparent that less detail of the dendritic structure is visible in the autoradiographs than in the photomacrographs owing to the limited resolution attainable with Mn 56. However, considerably more detail is revealed by the microphotometer traverses of the autoradiographs than can be distinguished on their enlargements.

The degree of dendritic heterogeneity (H^D) can be expressed conveniently as the ratio of adjacent maximum and minimum concentrations.[5] The manganese heterogeneities (H^D_{Mn}) of the dendrite spines and arms traversed in the three sections from Fig. 1, 2, and 3 and additional measurements fell in the ranges:

Specimen 1: $H^D_{Mn} = 1{\cdot}02–1{\cdot}36$

Specimen 2: $H^D_{Mn} = 1{\cdot}04–1{\cdot}40$

Specimen 3: $H^D_{Mn} = 1{\cdot}04–1{\cdot}42$

The true heterogeneities will be slightly greater than these because the use of a finite aperture size in the densitometer has an averaging effect on the concentrations measured and the true peak maxima and minima are greater than those recorded. The error in the heterogeneities from this effect probably only amounts to a few per cent, unless very narrow regions of widely varying composition exist between the dendrites or in the dendrite spines.

Examination of Figs. 1, 2, and 3 shows that the interdendritic regions with a high manganese content generally have increased hardness indicating that chemical heterogeneity has a considerable influence on mechanical properties. This effect cannot be attributed to manganese alone, as the segregation of other elements occurs with manganese, as shown by macro-etching. The microhardness values for the three sections from Figs. 1, 2, and 3 and additional

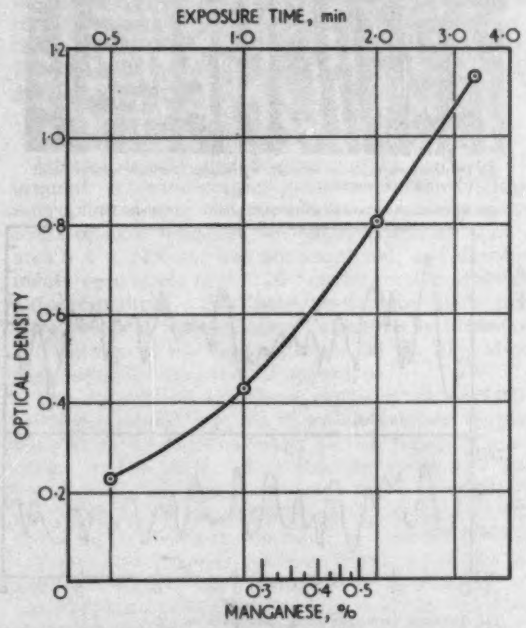


Fig. 4—Calibration curve showing the response of lantern plate emulsion to 2·9-MeV β-particles from Mn 56. The manganese-concentration scale shown is applicable to Figs. 1*a* and 1*c*

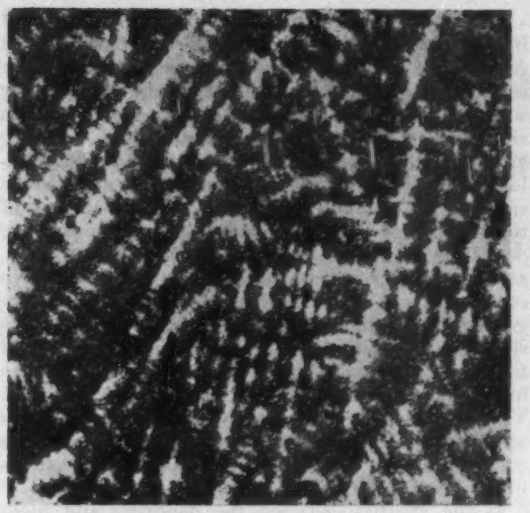
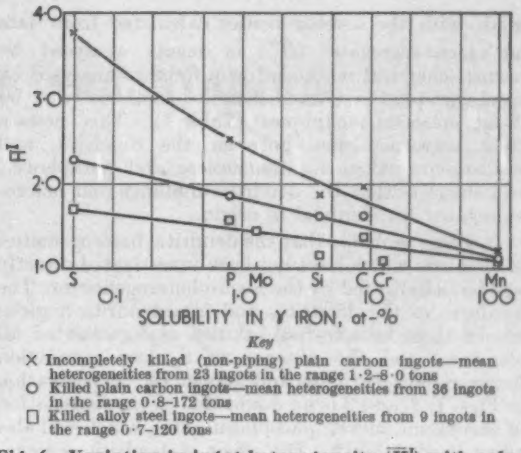


Fig. 5—Photomacrograph of the same steel as in Figs. 1, 2, and 3 after slow cooling from the fully austenitic condition. Etched in nital × 12



Key

× Incompletely killed (non-piping) plain carbon ingots—mean heterogeneities from 23 ingots in the range 1·2–8·0 tons
○ Killed plain carbon ingots—mean heterogeneities from 36 ingots in the range 0·8–172 tons
□ Killed alloy steel ingots—mean heterogeneities from 9 ingots in the range 0·7–120 tons

Fig. 6—Variation in ingot heterogeneity ($\overline{H}^I$) with solubility in austenite

microhardness surveys were found to be in the ranges:

Specimen 1: D.P.N. = 188–243
Specimen 2: D.P.N. = 161–225
Specimen 3: D.P.N. = 177–229

DISCUSSION OF RESULTS

Comparison of the manganese heterogeneities of the three sections examined shows that the ranges do not differ significantly from one another and it therefore appears that the segregation of manganese occurs to a similar extent in adjacent regions of the columnar and equiaxed zones. The hardness variations are also similar in all regions although the general level of hardness is significantly higher in the columnar zone.

The autoradiographic method has previously been used by Kohn[5] to investigate the dendritic segregation of phosphorus in small laboratory ingots, and the phosphorus heterogeneities were found to be in the range $H_P^D = 2·3–4·0$. This dendritic segregation is thus much more marked than that found for manganese (1·02–1·42) in the present investigation.

Cattier *et al.*[6] have also investigated the dendritic segregation of phosphorus by heavily etching ingot surfaces and then machining off the upstanding dendritic infillings. Heterogeneities calculated as the ratio of the analyses of the machinings and the mean composition of the samples are given in Table I. These and other heterogeneities calculated with respect to the mean composition are written $\overline{H}$ to distinguish them from the full-range heterogeneity H used previously. Direct comparison of the $\overline{H}_P^D$ values from Cattier *et al.* and the H_P^D autoradiographic values from Kohn is impossible, but the general agreement gives confidence in the autoradiographic method.

No direct confirmation is possible of the dendritic heterogeneities of manganese ($\overline{H}_{Mn}^D$) obtained from the present investigation, but a comparison can be

Table I

THE DEGREE OF HETEROGENEITY IN INGOT AND FORGED STEEL

Segregating Element	Dendritic Heterogeneity in Ingots, H^D		Macro Heterogeneity, $\overline{H}^M$				Ingot Heterogeneity, $\overline{H}^I$		
			In Ingots	In Forgings (2 : 1 reduction)			Killed Alloy	Killed Carbon	Non-Piping
	Autoradiography	Cattier Method	Chemical	Spectrographic	Microchemical	X-ray Emission	Chemical	Chemical	Chemical
Ni		0·99–1·08		1·06–1·10	1·04–1·11	1·1	1·02–1·08		
C		1·16–1·60	1·05–1·94		1·05–1·11	0·9	1·11–1·97	1·11–3·16	1·37–3·58
Mn	0·98–1·21		1·03–1·13	1·06–1·15	1·09–1·31	1·0	1·03–1·26	1·05–1·27	1·05–1·29
Cr				1·00–1·23	1·00–1·67	1·1	1·01–1·31		
Si			1·07–1·25	0·96–1·88	1·19–1·40	1·4	1·03–1·23	1·00–1·36	1·14–2·67
Mo				1·00–1·62	1·10–1·71	1·6			
Va				1·08–1·84	1·46–1·91	1·7			
P	($H_P^D = 2·3–4·0$)	1·16–3·08	1·79–3·86		1·60–3·30	1·9	1·06–2·25	1·18–3·92	1·39–5·64
S		1·00–2·22	1·61–4·77		1·71–3·29	1·6	1·29–2·56	1·27–6·11	1·41–8·94
No. of Reference	Present work, 5	6	7	8	8	9	11	11	11

made with the heterogeneities calculated from data on macro-segregates ($\overline{H}^{M}$) in ingots analysed by normal chemical methods[7] or in forgings analysed by spectrographic and microchemical methods[8] and by X-ray emission techniques[9] (Table I). This shows a close correspondence between the dendritic and macro-segregations for manganese and phosphorus, and suggests that the dendritic infillings and macro-segregates are identical in origin.

It seems probable that the dendritic heterogeneities of elements which have not been investigated directly will be as indicated by the macro-heterogeneities. The hardness of the dendrites and interdendritic regions would thus be affected by the segregation of all elements, and the absence of a close correlation between microhardness and manganese concentration in Figs. 1, 2, and 3 is no doubt due to the segregation of chromium, nickel, phosphorus, etc., which will also affect hardenability. The effect of dendritic segregation on transformation characteristics and hardenability has recently been discussed by Steven and Thorneycroft.[10]

The solidification of dendrites which are purer than the mean steel composition is accompanied by the enrichment of the adjacent liquid with the rejected elements and the entrapment of this enriched liquid by the intergrowing dendrites accounts for the inter-dendritic segregates. The macro-segregates are probably pockets of this liquid cut off from the main body of molten metal, and the same process of differential solidification also accounts for the concentration of solute in the last liquid to solidify in the ingot. These segregations are therefore closely related, and it is of interest to compare the overall ingot heterogeneity ($\overline{H}^{I}$) with the dendritic ($\overline{H}^{D}$) and macro-heterogeneities ($\overline{H}^{M}$). This has been done using data collected by the Ingots Committee of The Iron and Steel Institute on 9 alloy steel ingots,[11] 36 killed carbon steel ingots, and 23 incompletely killed (non-piping) carbon steel ingots, from which $\overline{H}^{I}$ has been taken as the ratio of the maximum and minimum concentrations of each element, in samples taken at standard positions in each ingot (Table I).

The overall ingot heterogeneities are very similar to those for the small-scale segregations, with the single exception of carbon which is segregated to a considerably greater extent on the ingot scale. The low values of $\overline{H}^{D}_{C}$ and $\overline{H}^{M}_{C}$ are the result of carbon diffusion which destroys the initial short-range concentration variations in dendritic and small-scale segregates. Carbon diffusion will have no significant effect on long-range concentration variations and it seems likely that the $\overline{H}^{I}_{C}$ values are equal to the initial carbon heterogeneities in dendritic and small-scale macro-segregates immediately after solidification. The influence of carbon diffusion on dendritic carbon heterogeneity is shown in Fig. 5 of a sample of the alloy steel used in the autoradiographic investigation in which, after furnace cooling from the fully austenitic condition, the dendrite spines are practically carbon-free ferrite. In this condition $\overline{H}^{D}_{C}$ would be extremely large and bear no relation to the value after solidification.

It has been found that smooth plots can be obtained if the mean ingot heterogeneities are plotted as a function of the logarithm of the solubility of each element in gamma-iron, for each class of ingot for which data are available Fig. (6). These plots serve to emphasize the effect of alloy content and complete killing in decreasing segregation. The gamma solubility is an expression of both electronic and atomic size factors on alloy behaviour, but the success of this function from simple binary systems in correlating data from complex systems must be largely fortuitous, and the plots must be regarded as empirical. No correlation can be obtained between the ingot heterogeneities and the ratio of the liquidus and solidus slopes in the binary diagrams which might be expected to influence coring phenomena, or with the difference in atomic radii between the solute atom and iron. The ingot heterogeneities may be taken to give an approximation to the ratio of the liquidus and solidus compositions in the appropriate polynary systems under ingot solidification conditions.

If the identity between the dendritic and ingot heterogeneities is valid, it seems likely that the beneficial effects of alloy content in decreasing ingot segregation may apply to dendritic segregation. This also suggests that other analogies may exist between the two modes of segregation, and ingot defects such as axial porosity may be present in inter-dendritic regions which could contribute to the inferior transverse properties of wrought materials if the porosity were not completely welded up during hot working.

Acknowledgments

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The Effect of Tantalum and Niobium on the Tempering of Certain Vanadium and Molybdenum Steels

By Arun K. Seal, B.Sc., B.Eng., Ph.D., and R. W. K. Honeycombe, M.Sc., Ph.D.

SYNOPSIS

A study has been made of the carbides formed during the tempering of several simple vanadium and molybdenum steels, in which the onset of secondary hardening can be directly related to the precipitation of V_4C_3 and Mo_2C by use of electron microscopic and electron diffraction methods. Small additions (0·05–0·25%) of tantalum and niobium have a considerable influence on the secondary-hardening characteristics of these steels. The evidence suggests that the hardness peaks are raised because these strong carbide-forming elements enter into solid solution in the existing carbide phases and increase the coherency stresses. Tantalum and niobium also markedly restrain the growth of the alloy carbides and so delay softening of the steels at elevated temperatures. Detailed interpretation is made more difficult as small amounts of tantalum- and niobium-rich carbide phases are also formed. 1498

Introduction

IN A RECENT PAPER[1] the present authors have examined the behaviour of some steels containing chromium and vanadium, in particular after tempering in the range 400–700° C when alloy carbides are formed. By using recently developed extraction-replica techniques for electron microscopy and electron diffraction, it was possible to relate directly the onset of secondary hardening and the precipitation of the alloy carbide. In the present paper similar results on molybdenum steels are described.

Our investigations showed that small additions of vanadium influenced markedly the tempering behaviour of a 9% Cr steel by its effect on the precipitation of the Cr_7C_3 phase. The growth of this precipitate was retarded, and as the vanadium content increased to 1%, secondary hardening absent in the plain chromium steel occurred to some degree, although the predominant carbide type Cr_7C_3 did not change. This work indicated that deliberate variation of the composition of the existing carbide phase influenced both the relationship of the precipitate to the matrix in the early stages of precipitation, and the tendency of this precipitate to coarsen.

In the present paper this approach has been extended to vanadium and molybdenum steels of simple basic composition in which V_4C_3 and Mo_2C are the predominant alloy carbides in the tempering range in which secondary hardening occurs. Small additions of the strong carbide-forming elements tantalum and niobium have been made to these steels; these elements were chosen because their carbides appear to be substantially soluble[2] in V_4C_3 and Mo_2C. Furthermore, TaC and NbC possess very high melting points, and thus should promote stability to carbide phases with which they form solid solutions. The present work describes the extent to which these additions influence the stability of the carbide precipitates, and the consequent effect on the secondary hardening phenomenon.

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Dr. Seal, who is Assistant Professor of Metallurgy, Bengal Engineering College, Howrah, was formerly a research student at the Department of Metallurgy, University of Sheffield. Professor Honeycombe is with the Department of Metallurgy, University of Sheffield.

EXPERIMENTAL METHODS

The general approach to the problem was the same as that reported in our previous paper,[1] namely, the steels were quenched then tempered over a range of temperatures. The hardness was measured at room temperature, and microscopic examinations were made both optically and with the electron microscope. Electron diffraction studies were made on carbon extraction replicas, while electrolytically extracted carbides were examined by X-ray diffraction.

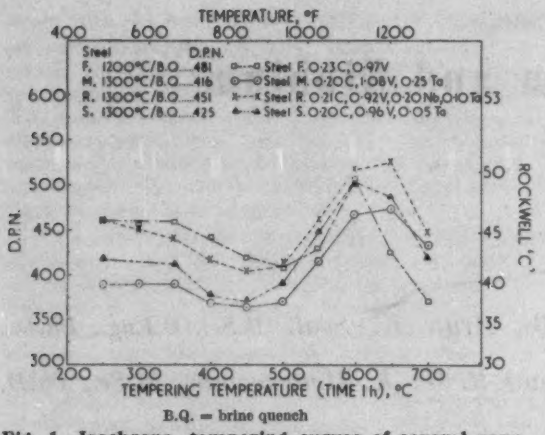
Preparation of the Steels and their Heat-treatment

The steels were melted in a small high-frequency furnace and cast into 7½-lb tapered ingots approximately 2 in. square which were forged down to 1-in. dia. rods from which the decarburized layer was removed by machining. The chemical analyses of the steels studied are shown in Table I.

Table I

CHEMICAL ANALYSES OF STEELS

Steel Code Letter	Weight-Percentage									
	C	Cr	V	Mo	Ta	Nb	Si	Mn	S	P
F	0·23		0·97				0·20	0·33	0·042	0·017
M	0·20		1·08		0·25		0·42	0·37	0·028	0·036
R	0·21		0·92		0·10	0·20	0·28	0·40	0·030	0·036
S	0·19		0·96		0·049		0·30	0·40	0·019	0·032
K	0·23			0·99			0·23	0·33	0·028	0·028
N	0·19			3·61			0·21	0·35	0·028	0·028
P	0·20			3·83	0·22		0·30	0·34	0·037	0·046
X	0·22	2·05	0·92		0·25		0·30	0·39	0·031	0·030
Y	0·22	1·99	1·01				0·32	0·47	0·031	0·037



B.Q. = brine quench

Fig. 1—Isochrona tempering curves of several vanadium steels

All the alloying elements were added as their ferro-alloys except tantalum which was added in the form of pure scrap sheet.

Specimens were homogenized in argon for 4 h, the temperature selected being high enough to take most of the carbides into solution. To satisfy this requirement, steels *F*, *K*, and *N* were homogenized at 1200° C whereas the other steels (containing Nb and Ta) were homogenized at 1300° C. This inevitably resulted in coarse grain sizes which did not matter for the experiments contemplated. Tempering treatments up to 1000 h were carried out in salt baths controlled to ± 3° C. Tempering at 700° C was done in lead baths. The specimens were water quenched from the tempering temperatures.

Hardness Measurements

Vickers hardness tests were done with a load of 20 kg. A mean of at least three indentations was taken as the hardness value.

Extraction of Carbides

The carbides were extracted electrolytically from the tempered specimens by electrolysis in 5% HCl at a current density of 0·025 A/cm² using a glycerine layer at the bottom of the cell. The carbides were separated by centrifuging and X-ray photographs were taken of the extracts using a 9-cm camera.

Electron Microscopy

The tempered specimens were electropolished in a bath containing 950 ml glacial acetic acid and 50 ml perchloric acid 1·56 sp. gr. using an applied voltage of 70–80 for 1–1½ min. As in the previous work[1] carbon extraction replicas were prepared for electron microscopy by the method of Smith and Nutting.[10] This enabled the positive identification by electron diffraction of the carbide phases at an early stage of their growth. Electron microscopy and diffraction were carried out in a Metropolitan-Vickers E.M.3 instrument with a resolution of 50 Å, while a few critical replicas where the fine precipitate was less than 50 Å dia. were examined in a Siemens Elmiskop 1 having a resolution better than 10 Å.

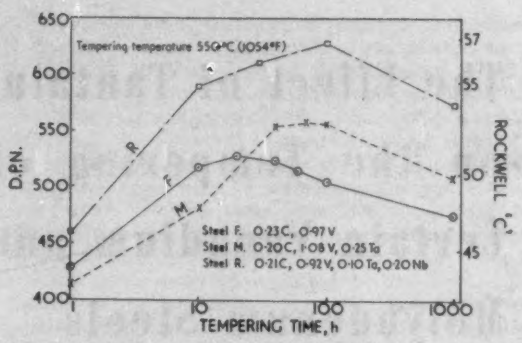


Fig. 2—Isothermal tempering curves for three vanadium steels tempered at 550° C

RESULTS

Effect of Tantalum and Niobium on the Tempering of a 1% Vanadium Steel

The behaviour of steel *F* containing 0·97% V and 0·23% C was discussed in detail in the previous paper,[1] where it was shown that the optimum secondary hardness could be developed after 475 h at 500° C as a result of the precipitation of V_4C_3 as small rodlets (about 20 Å dia. × 200 Å long). It was decided to add small quantities of tantalum and niobium (containing tantalum) to this steel as the carbides of these elements are isomorphous with V_4C_3 and thus a single solid-solution carbide phase would be expected to form. Moreover in view of the high melting points of TaC and NbC, and of the probable lower rates of diffusion of these elements in ferrite, it was thought that the alloy carbide precipitates would be stabilized, remaining finer than the 'un-alloyed' V_4C_3 after similar tempering treatments.

Isochronal Hardness Changes—The results of one hour tempering treatments of the steels *F*, *M*, *R*, and *S* are shown in Fig. 1. While it is obvious from isothermal experiments that these isochronal curves do not reveal the optimum behaviour for each steel, certain general facts can be recognized. The variation in hardness on brine quenching is partly due to differences in austenitizing temperatures, and also to differences in grain size with consequent variations in the as-quenched bainitic structure. The plain vanadium steel *F* shows a peak hardness at 600° C but the hardness falls off markedly above this temperature. Steels *M* and *R*, on the other hand, do not reach a peak hardness until 50° C higher and even at 700° C their hardness is at least 50 points above that of steel *F*. Steel *R* contains both niobium and tantalum which is clearly more effective than the straight tantalum addition, although we cannot say whether this is due to the greater effectiveness of niobium or to the combined effect of tantalum and niobium. Steel *S*, although it contains only 0·05% Ta (2 at-% of the total vanadium content of the steel), resists softening much more than does steel *F* with no tantalum.

Isothermal Hardness Changes—The steels *F*, *M*, and *R* were tempered for various times up to 1000 h at three temperatures 500° C, 550° C, and 700° C. At 500° C the plain vanadium steel *F* developed a hardness maximum (600 D.P.N.) after approximately

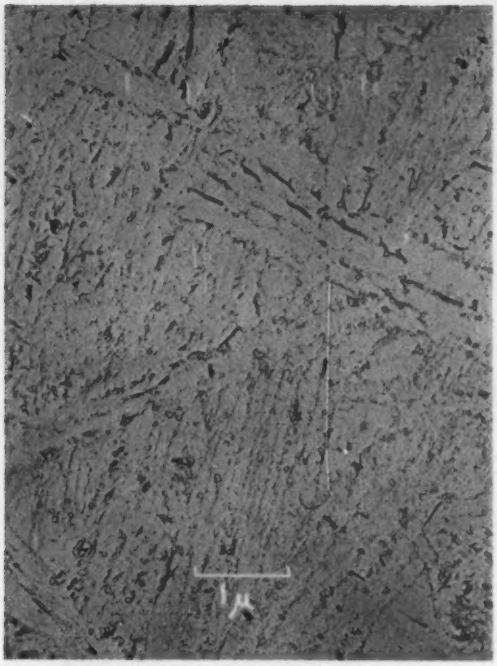


Fig. 3—Steel *M* as brine-quenched. Carbon replica × 15,000

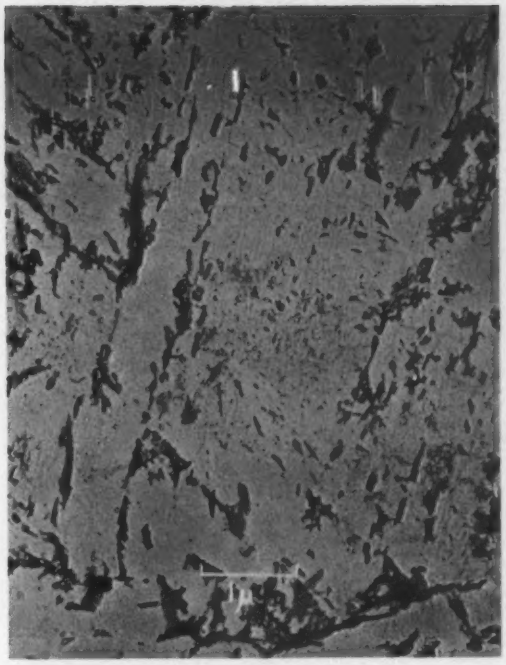


Fig. 4—Steel *M* tempered 1 h at 500° C. Carbon extraction replica × 15,000

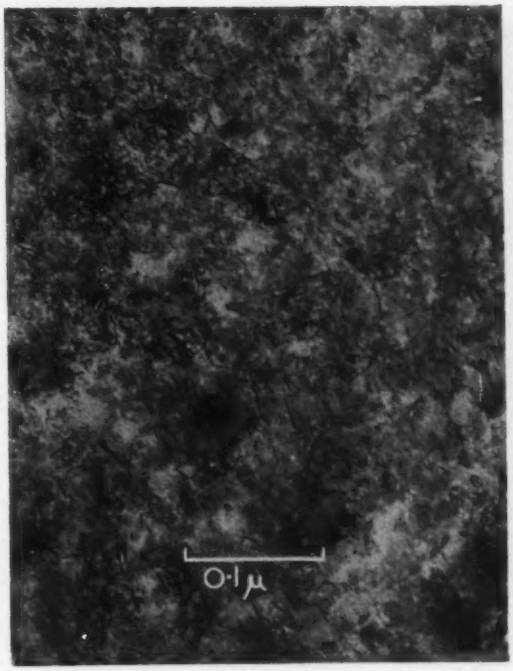


Fig. 5—Steel *F* tempered 100 h at 500° C. Carbon extraction replica × 200,000

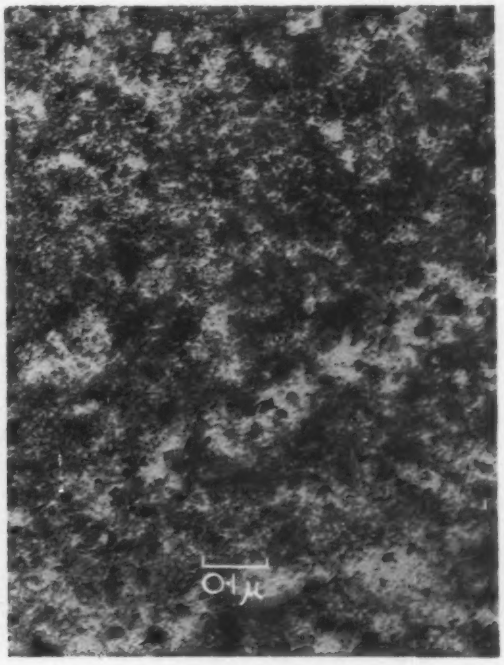


Fig. 6—Steel *R* tempered 100 h at 550° C. Carbon extraction replica × 100,000

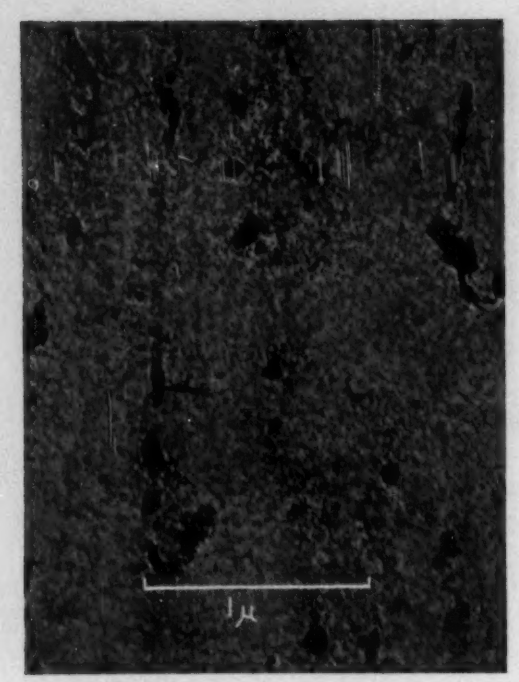


Fig. 7—Steel *M* tempered 1 h at 600° C. Carbon extraction replica × 35,000

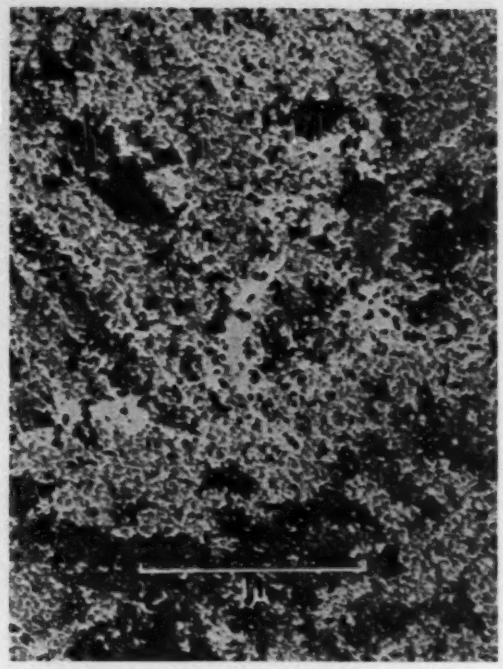


Fig. 8—Steel *F* tempered 1 h at 600° C. Carbon extraction replica × 35,000

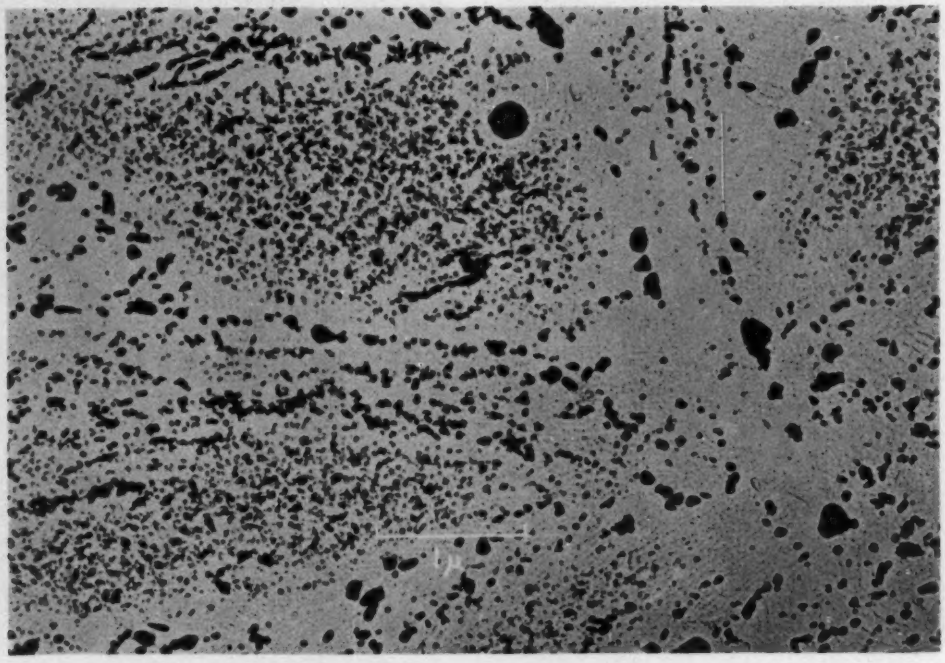


Fig. 9—Steel *F* tempered 100 h at 700° C. Carbon extraction replica × 24,000

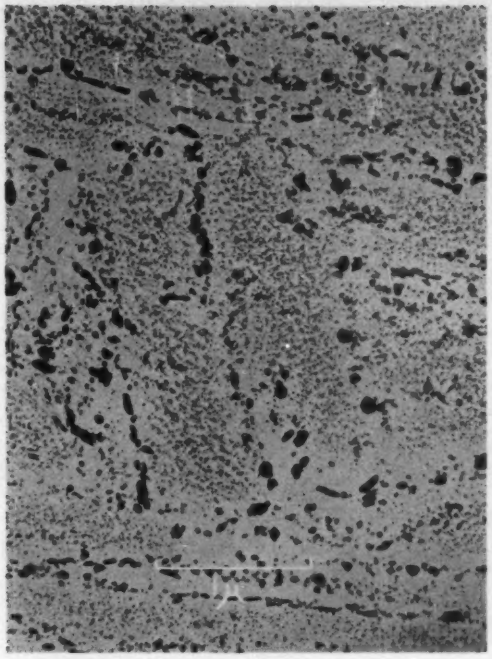


Fig. 10—Steel *M* tempered 100 h at 700° C. Carbon extraction replica × 24,000

Fig. 11—Steel *N* tempered 1000 h at 500° C. Carbon extraction replica × 100,000

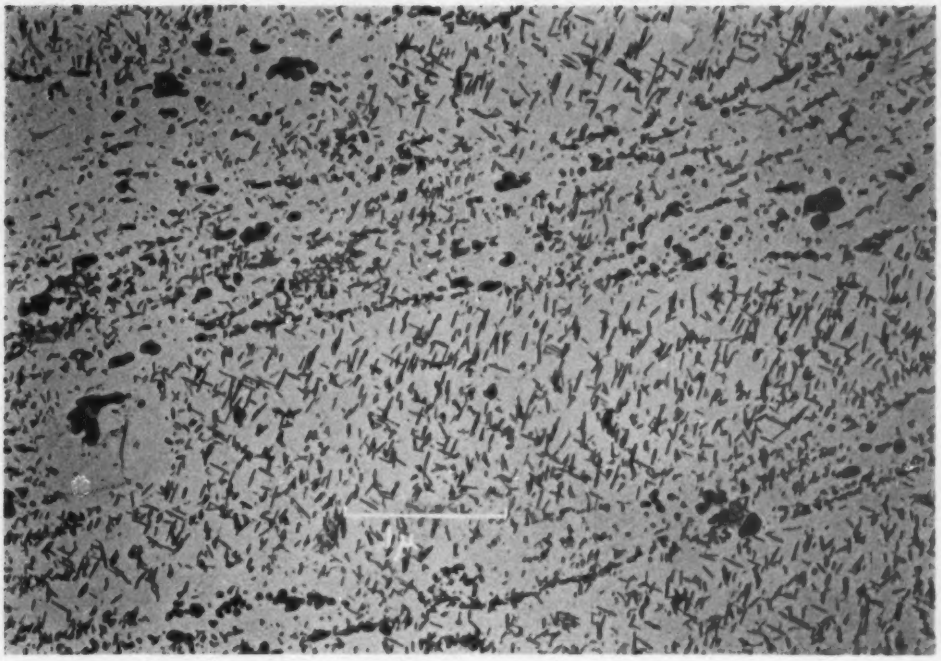


Fig. 12—Steel *N* tempered 1 h at 700° C. Carbon extraction replica × 24,000

Fig. 13—Steel *N* tempered 1000 h at 550° C. Carbon extraction replica × 35,000

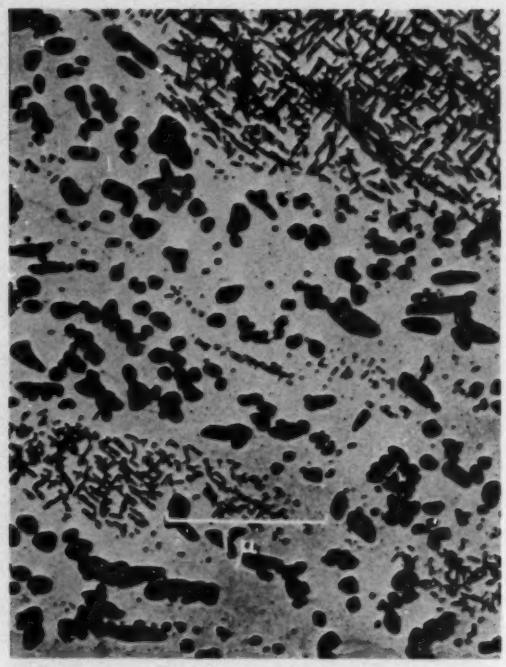


Fig. 14—Steel *N* tempered 10 h at 700° C. Carbon extraction replica × 24,000

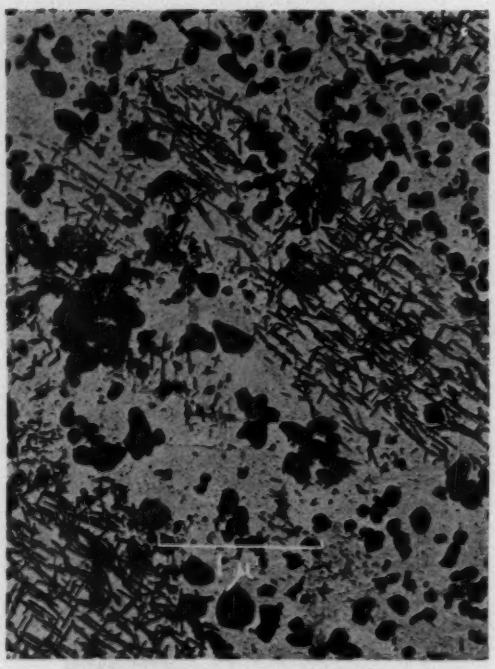


Fig. 15—Steel *P* tempered 10 h at 700° C. Carbon extraction replica × 24,000

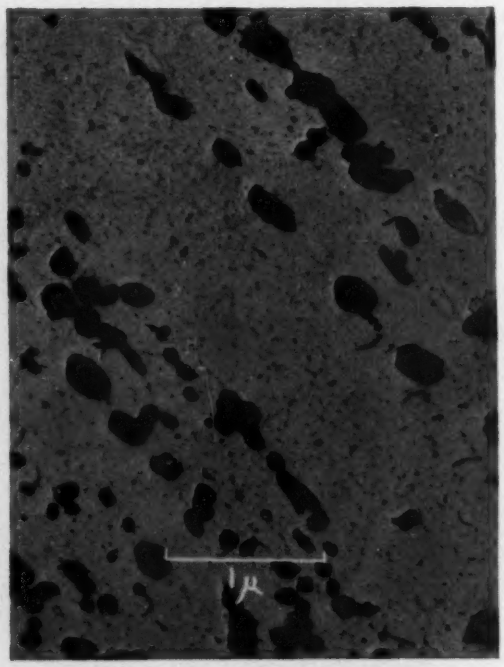


Fig. 16—Steel *P* tempered 1000 h at 700° C. Carbon extraction replica × 24,000

Table II

IDENTIFICATION OF CARBIDES IN TEMPERED STEELS *F*, *M*, AND *R*
Information about Carbide Types on Tempering at Different Temperatures

Steel	Tempering Temperature, °C	Tempering Time							
		1 h		10 h		100 h		1000 h	
		X-ray	E.M. + E.D.	X-ray	E.M. + E.D.	X-ray	E.M. + E.D.	X-ray	E.M. + E.D.
F	500	Fe_3C	Fe_3C	Fe_3C	$Fe_3C + V_4C_3$	$Fe_3C + V_4C_3$ (v.w.)	$Fe_3C + V_4C_3$	$V_4C_3 + Fe_3C$	$V_4C_3 + Fe_3C$
0·23% C	550	Fe_3C	$Fe_3C + V_4C_3$	n.d.	$Fe_3C + V_4C_3$	V_4C_3 (w.)	$V_4C_3 + Fe_3C$	n.d.	n.d.
0·97% V	700	V_4C_3	V_4C_3	V_4C_3	V_4C_3	n.d.	V_4C_3	V_4C_3	V_4C_3
M	500	n.d.	n.d.	n.d.	$Fe_3C + V_4C_3$	n.d.	$Fe_3C + V_4C_3$	V_4C_3 (v.w.) + TaC (v.w.)	$V_4C_3 + Fe_3C$
0·20% C	550	Fe_3C	$Fe_3C + V_4C_3$	n.d.	$Fe_3C + V_4C_3$	n.d.	$V_4C_3 + Fe_3C$	V_4C_3 + TaC (w.) + Fe_3C (w.)	$V_4C_3 + Fe_3C$
1·08% V	700	V_4C_3 + TaC (v.w.)	V_4C_3	V_4C_3 + TaC (v.w.)	V_4C_3	n.d.	V_4C_3	V_4C_3 + TaC (w.)	V_4C_3
0·25% Ta									
R	500	n.d.	Fe_3C	n.d.	n.d.	n.d.	$Fe_3C + V_4C_3$	V_4C_3 (v.w.) NbC (v.w.)	$V_4C_3 + Fe_3C$
0·21% C	550	n.d.	n.d.	n.d.	$Fe_3C + V_4C_3$	n.d.	$V_4C_3 + Fe_3C$	V_4C_3 + NbC (w.) + Fe_3C (v.w.)	$V_4C_3 + Fe_3C$
0·92% V									
0·20% Nb	700	V_4C_3 + NbC (v.w.)	V_4C_3	V_4C_3 + NbC (w.)	V_4C_3	V_4C_3 + NbC (w).	V_4C_3	V_4C_3 + NbC (w.)	V_4C_3
0·10% Ta									

Key: v.w. = very weak w. = weak n.d. = not determined E.M. = electron microscope E.D. = electron diffraction

500 h, whereas the hardness of steels *R* and *M* was still rising after 1000 h. After this time the hardness of steel *F* had fallen to 550 D.P.N.

At 550° C the differences between the three steels were even more pronounced than at 500° C. Figure 2 shows the results up to 1000 h. The plain vanadium steel *F* has reached a maximum hardness of 525 D.P.N. after about 20 h, whereas *M* took just under 100 h to reach a peak hardness of 550 D.P.N. Steel *R* now shows much more impressive secondary hardening than either *F* or *M* with a peak hardness of 625 after 100 h.

At 700° C, no peak was observed and the hardness fell continuously with time, but even after 100 and 1000 h there were distinct differences between the 3 steels. After 1000 h, steel *M* remained slightly harder than steel *R*, and both were significantly harder than steel *F*.

Microstructure and Carbide Compositions—The as-quenched specimens were all bainitic (Fig. 3). On electrolytic extraction, cementite was detected in the residue in the case of steels *M* and *R*; however, no alloy carbides were found. Examination by means of extraction replicas of specimens tempered in the range 250–450° C revealed only cementite in an acicular ferrite matrix. This cementite gradually coarsened with increasing temperature leading to the fall in hardness observed in all of the four steels in the range 350–500° C. After 1 h at 500° C, the cementite particles in steel *M* were 1000–3000 Å long × 200–400 Å dia. (Fig. 4).

As the secondary-hardness peak developed, both the optical and electron microstructures showed the gradual disappearance of the relatively coarse cementite particles. The electron microscope, however, showed in addition the development of the alloy carbide precipitation. This could be resolved in the plain vanadium steel *F* after 100 h at 500° C (prior to the peak hardness) as rods or threads about 15–25 Å wide × 50–200 Å long (Fig. 5). Electron diffraction studies gave the pattern corresponding to V_4C_3 at this stage whereas X-ray photographs of electrolytic carbide extracts did not. On the other hand, steel *R* had to be tempered 100 h at 550° C to obtain a microstructure approximating to this; even so the rodlets of V_4C_3 are barely visible (Fig. 6) although the alloy carbide gives a definite electron diffraction pattern after only 10 h at 550° C. In Figs. 5 and 6 there is also some evidence of disc-shaped particles. A summary of the microscopic, electron, and X-ray diffraction findings of the carbide structures in steels *F*, *M*, and *R* is given in Table II for 1, 10, 100, and 1000 h tempering treatments. The table shows that electron microscopy together with electron diffraction is a more sensitive method of detection than X-ray diffraction examination of carbide extracts. However, the X-ray method proved superior in detecting small concentrations of other carbide phases, namely, TaC and NbC, although these may well have formed at temperatures lower than those at which they are first observed in powder photographs.

As the peak hardness is passed, the rod-like forms are replaced by more spheroidal particles characteristic of the over-aged condition. Hardness differences in the steels still persist and are reflected in the differences in microstructure. Figures 7 and 8 compare steels *M* and *F* after tempering 1 h at 600° C; while the spheroidal particles of V_4C_3 are not resolvable in Fig. 7, they are in Fig. 8. At 700° C, the electron microstructures become much clearer and the more advanced precipitation of V_4C_3 at both prior austenitic and ferritic grain boundaries (Fig. 9) is evident. However, even after long periods at 700° C there is still a fine precipitate within the grains which is gradually coarsening. The differences between steel *F*

Table III
INTERPLANAR SPACINGS OF CARBIDES IN STEELS *F*, *M*, AND *R*
***d*-values, Å**

h, k, l	Steel *F*	Steel *M*	Steel *R*	According to A.S.T.M. Index		
				V_4C_3	TaC	NbC
111	2·390	2·393 2·509	2·404 2·531	2·40	2·56	2·54
200	2·073	2·074 2·173	2·080 2·197	2·07	2·22	2·20
220	1·467	1·470 1·543	1·476 1·554	1·47	1·57	1·55
311	1·252	1·255 1·315	1·258 1·328	1·25	1·34	1·33
222	1·200			1·20	1·28	1·27

and steel *M* is shown in Figs. 9 and 10 taken from steels tempered for 100 h at 700° C. Steel *F* has clearly the coarser structure.

TaC and NbC were detected after 1000 h at 500° C in steels *M* and *R* respectively by X-ray diffraction (Table II). It was impossible to distinguish microscopically between these carbides and the V_4C_3 within the grains; but both were finer than the V_4C_3 precipitate in steel *F* (Fig. 9).

Steel *S* was made in an attempt to produce a steel without TaC as a separate phase. No TaC was detected in the carbide extracts from steel *S*, but this steel on tempering 100 h at 700° C gave microstructures comparable to those of steels *M* and *R*, i.e. finer than those of *F*. Taken with the hardness data (Fig. 1) this indicates that tantalum in solid solution in the V_4C_3 phase has a pronounced effect on its dispersion.

Measurement of d-values of Carbides from Steels F, M, and R—Comparison of the X-ray diffraction patterns of the carbide extracts from steels *F*, *M*, and *R* after a tempering period of 1000 h at 700° C showed a small but significant shift in the vanadium carbide lines of steels *M* and *R* as compared with those of steel *F* (Table III).

The interplanar spacings of pure V_4C_3, TaC, and NbC are given for comparison but it should be emphasized that even in steel *F* the V_4C_3 should have some iron in solid solution. Similar considerations apply to the TaC and NbC measurements; the NbC detected in steel *R* is more accurately described as (NbTa)C. A slight shift of the V_4C_3 diffraction lines was also observed from samples of carbide extracted from steel *S*.

Effect of Prior Cold Deformation on the Secondary Hardening of Steel F

Having established the fact that the secondary hardening of a 1% V steel is due to precipitation of V_4C_3,[1] it was decided to determine the effect of cold work which has been studied in other age-hardening alloys. The steel was first tempered for 1 h at 550° C to obtain a relatively soft condition (approx. 425 D.P.N.) prior to secondary hardening (Fig. 1), then specimens were compressed by 10·3, 33·5, and 61·1%. An undeformed specimen was also treated as a control. The secondary hardening behaviour at 500° C was studied by intermittent hardness measurements at suitable time intervals and by metallographic observations on selected specimens.

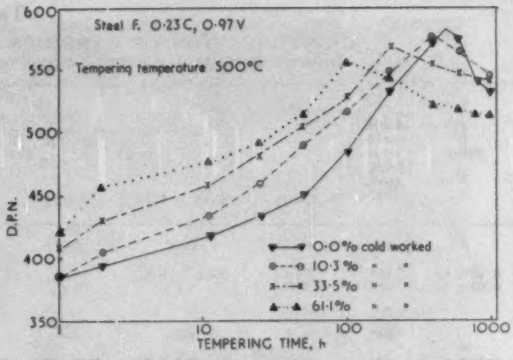


Fig. 17—Effect of cold work on the secondary hardening of a 1% V steel

The results are summarized in Fig. 17. The hardnesses after 1 h represent the values after cold working. The peak hardness is moved towards shorter times and lower hardness by increasing amounts of cold work. The undeformed sample reached a peak hardness of 580 D.P.N. in 475 h whereas the specimen deformed 61·1% reached 555 D.P.N. in 100 h. Electron microscope examinations after comparable times revealed that the vanadium carbide precipitate was coarser in the most heavily deformed specimens.

Tempering of Three Mo Steels K, N, and P

Two simple Mo steels, *K* containing 0·23% C and 0·99% Mo, and *N* containing 0·19% C and 3·61% Mo were chosen for investigation. Steel *P* was the same as steel *N* except for the addition of 0·22% Ta, a modification similar to that in the vanadium steel *M*.

Isochronal Hardness Changes—The results of hardness tests on these 3 steels after tempering for 1-h periods over the temperature range 250–700° C are shown in Fig. 18. Steel *K* shows a marked drop in hardness up to 500° C above which a slight secondary hardening develops. Steel *N* with an increased molybdenum content does not soften markedly in the range 250–500° C, and between 500° and 600° C develops a well-defined secondary-hardening peak. On the other hand, steel *P* containing in addition 0·22% Ta has a still more pronounced hardness peak which persists up to 650° C. Furthermore, even after tempering at 700° C, its hardness is nearly 100 Vickers units above that of steel *N*. It should be noted that steel *P* was austenitized at 1300° C to ensure that all the tantalum was in solid solution.

Isothermal Hardness Changes—The steels *K*, *N*, and *P* were tempered for various times up to 1000 h at 500° C, 550° C, and 700° C. At 500° C, differences between the 3 steels were most pronounced (Fig. 19). While the low-molybdenum steel *K* reached a peak hardness of 435 D.P.N. after 100 h, steel *N* had attained a hardness of 590 after 1000 h, while the hardness of steel *P* had risen as high as 700 D.P.N. at this stage. At 550° C, the peak differences between steels *N* and *P* were much less pronounced, each reaching a peak hardness of about 600 D.P.N. after 100 h. However, on over-ageing, steel *P* softened less

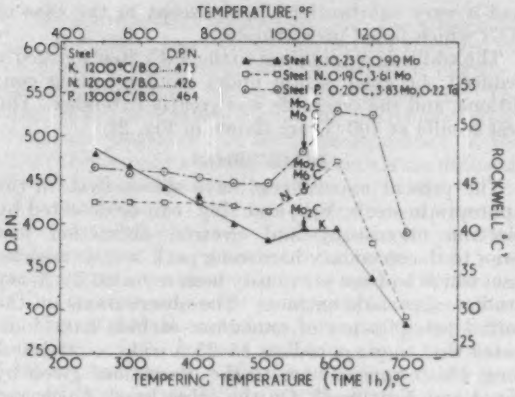


Fig. 18—Isochronal tempering curves for three molybdenum steels

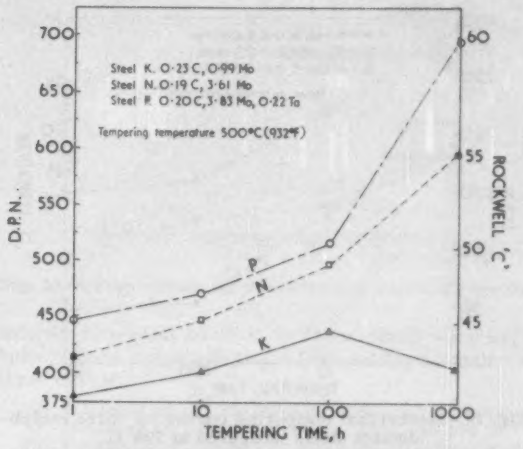

Steel K, 0·23 C, 0·99 Mo
Steel N, 0·19 C, 3·61 Mo
Steel P, 0·20 C, 3·83 Mo, 0·22 Ta
Tempering temperature 500°C (932°F)
D.P.N.
ROCKWELL 'C'
TEMPERING TIME, h

Fig. 19—Isothermal tempering curves for three molybdenum steels tempered at 500° C

readily, and after 1000 h had a hardness of 500 D.P.N., whereas steel *N* had fallen to below 400 D.P.N. On the other hand, the hardness of steel *K* fell continuously on tempering at 550° C from 390 to 370 D.P.N.

Tempering at 700° C resulted in a continuous fall in hardness in each of the 3 steels (Fig. 20) but pronounced differences in hardness still existed after 1000 h at 700° C.

Microstructure and Carbide Compositions—The 3 steels, as brine-quenched, all possessed bainitic structures. X-ray examination of extracts from specimens revealed the presence of imperfect cementite, but no alloy carbides. Extraction replicas showed clearly the cementite particles in the bainitic structure.

Specimens of steel *K* tempered in the range 250–500° C showed a progressive growth of cementite as in the straight vanadium steel *F*, which accounted for the gradual decrease in hardness. In steels *N* and *P* no marked changes in the microstructure were observed in the range 250–500° C. The increased molybdenum content has clearly suppressed the growth of the cementite particles.

The information obtained from electron microscopic and electron diffraction examination, and by X-ray diffraction of carbide extracts from specimens tempered for 1, 10, 100, and 1000 h at different temperatures is summarized in Table IV.

In steels *N* and *P*, Mo_2C was first detected in extraction replicas after 1 h at 550° C (*see* Fig. 18), whereas the carbide was not found by X-ray diffraction of the carbide extracts until 1000 h at 550° C, by which time the precipitate was much coarser and the steels over-aged. In the early stages, the Mo_2C diffraction patterns were imperfect and may be from a transitional structure. The first occurrence of Mo_2C corresponded with the start of the rise in hardness (Fig. 18), but the situation was complicated by the simultaneous detection of M_6C in steels *N* and *P*. This is a double carbide of iron and molybdenum of composition Fe_3Mo_3C or Fe_4Mo_2C. When the temperature of tempering was raised to 700° C, Mo_2C was gradually replaced by M_6C which became the sole carbide present after 1000 h at this temperature.

Steel *K* also precipitated Mo_2C during the secondary-hardening range but no M_6C was detected; moreover, the iron carbide was not entirely replaced by the alloy carbide even after long periods at 700° C. After 1000 h at 700° C, X-ray examination of the carbide extract indicated that the Mo_2C had been replaced by the M_aC_b type, a double carbide of iron and molybdenum first reported by Kuo.[3] Electron microscopic examination indicates that this transformation is not separately nucleated in the ferrite.

While Mo_2C could be detected by electron diffraction from extraction replicas at or even before the peak hardness was reached, it was extremely difficult to resolve the microstructures. However, using a high-resolution microscope it was possible to detect at this stage carbide particles about 25–50 Å wide × 200–500 Å long. Figure 11 shows steel *N* in this condition after tempering 1000 h at 500° C. After tempering this steel a similar time at 550° C, the Mo_2C carbide particles had grown substantially (Fig. 13) and the Widmanstätten pattern could be discerned. Also in Fig. 13 small spheroidal particles can be seen; these are M_6C particles at the earliest stage at which they could be identified with any certainty. At this stage the steel is well over-aged and microscopic examination leaves little doubt that the Mo_2C is primarily responsible for the secondary hardening. Comparison of the structure of steels *N* and *P* showed that after the same heat-treatments the Mo_2C particles were smaller in the latter.

Micro-examination of specimens of steels *N* and *P* tempered at 700° C showed clearly the rapid coarsening of M_6C at the expense of the Mo_2C needles. Figure 12 shows the beginning of growth of M_6C in steel *N* tempered 1 h at 700° C when the grains contain mainly Mo_2C. After 10 h (Fig. 14) the M_6C has replaced much of the Mo_2C. At this stage it is interesting to compare the structure of steels *N* and *P* (Figs. 14 and 15); the only detectable difference appears to be a very fine precipitate in the background in steel *P*. This may be a TaC-rich phase, but it was not detected in the carbide extracts. After 1000 h at 700° C all the Mo_2C has disappeared, but in steel *P* a fine background precipitate can still be detected (Fig. 16).

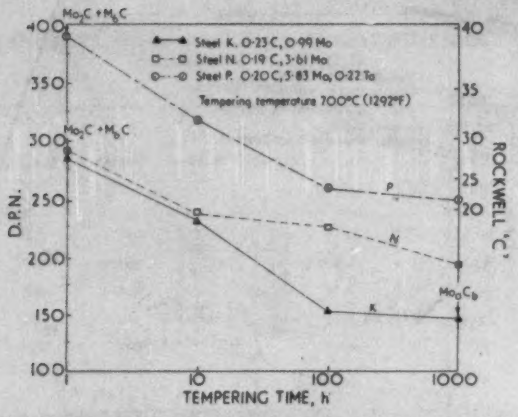

Steel K. 0·23 C, 0·99 Mo
Steel N. 0·19 C, 3·61 Mo
Steel P. 0·20 C, 3·83 Mo, 0·22 Ta
Tempering temperature 700°C (1292°F)
D.P.N.
ROCKWELL 'C'
TEMPERING TIME, h

Fig. 20 —Isothermal tempering curves for three molybdenum steels tempered at 700° C

Effect of Tantalum on Creep Properties of a Cr–V Steel

Relatively minor additions of tantalum and niobium to vanadium and molybdenum steels have now been shown to have a great influence on the secondary-hardening characteristics. It was considered important to see whether such an influence would be found also in the creep properties of the steels at elevated temperatures. Two steels *X* and *Y* (*see* Table I) based on 1% V were used for these tests with 2% Cr added to reduce oxidation. This addition did not alter the basic carbides occurring during the heat-treatment. No detailed attempt was made to determine the optimum heat-treatment for best creep properties, but the two steels, one with tantalum, one without, were tested after comparable heat-treatments and significant differences noted. The prior heat-treatment was designed to get all the carbides into solid solution before quenching; consequently the grain size was large. The creep tests were carried out at stresses of 9 tons/in² at 600° C and 2 tons/in² at 700° C. The results are summarized in Table V from which it can be seen that the tantalum addition had a very substantial effect, except in the case of *XC1* which failed prematurely.

The addition of tantalum to the V–Cr steel markedly reduced the creep strain under similar testing conditions, and the creep life was greatly extended. The test results at 700° C are shown in Fig. 21.

DISCUSSION

The present experiments have shown that, in the appropriate steels, V_4C_3 and Mo_2C can be detected by electron microscopy and electron diffraction just prior to the secondary-hardening peak, a clear association which had not previously been revealed by X-ray studies of carbide extracts. The observations on the initial precipitation of vanadium carbide have indicated that they are rodlets 15–25 Å wide × 50–100 Å long which approximate to the dimensions given by Kuo[4] and Nutting.[5*] On the other hand, Koch and Wiester[6] reported them to be spherical (~ 200 Å dia.); clearly this describes the condition of the precipitate in the slightly over-aged condition.

The persistent acicular habit of Mo_2C has been reported by other investigators,[7, 8, 9] and the present results agree with those of Kuo[7] in indicating that in the early stages the needles are 25–50 Å wide × 200–500 Å long. The electron diffraction photographs in the present investigation provide some evidence for a transitional structure, or at least, an imperfect Mo_2C structure. Wever and Schrader consider that Mo_2C can form both in the ferrite and directly from cementite, but in the present investigation only evidence for the former mechanism was obtained. The initial spheroidal habit of the M_6C particles and their subsequent rapid growth suggest strongly that this carbide has little influence on the secondary-hardening characteristics of the steels concerned.

* Smith and Nutting[11] in a recent paper claim that the initial vanadium carbide particles are ellipsoid in shape, the axial dimensions being 60 Å, 40–60Å, and 25Å. These figures were obtained by analyses of the line breadths in electron diffraction patterns and cannot be very precise. The present observations do not exclude the possibility of disc-shaped particles being present (*see* Figs. 5 and 6).

Table IV

IDENTIFICATION OF CARBIDES IN TEMPERED STEELS *K*, *N*, AND *P*
Information about Carbide Types on Tempering at Different Temperatures

Steel	Tempering Temperature, °C	Tempering Time: 1 h		10 h		100 h		1000 h	
		X-ray	E.M. + E.D.	X-ray	E.M. + E.D.	X-ray	E.M. + E.D.	X-ray	E.M. + E.D.
K	500	Fe_3C	Fe_3C	Fe_3C	Fe_3C + Mo_2C (I)	Fe_3C	Fe_3C + Mo_2C (I)	Fe_3C	Fe_3C + Mo_2C (I)
0·23% C 0·99% Mo	700	Fe_3C + Mo_2C (v.w.)	Fe_3C + Mo_2C	Fe_3C + Mo_2C	Fe_3C + Mo_2C	Mo_2C + Fe_3C	Mo_2C + Fe_3C	$M_{23}C_6$ + Fe_3C	$M_{23}C_6$ + Fe_3C
N	500	Fe_3C	Fe_3C	n.d.	n.d.	n.d.	n.d.	Blank	Mo_2C (I)
0·19% C	550	Blank	Fe_3C + Mo_2C (I) (v.w.)	Blank	Mo_2C (I)	n.d.	Mo_2C (I)	Mo_2C	Mo_2C + M_6C
3·61% Mo	700	Mo_2C	Mo_2C + M_6C	Mo_2C + M_6C	Mo_2C + M_6C	n.d.	M_6C + Mo_2C	M_6C	M_6C
P	500	Fe_3C	Fe_3C	n.d.	n.d.	n.d.	n.d.	Blank	Mo_2C (I)
0·20% C	550	n.d.	Fe_3C + Mo_2C (I) (v.w.)	n.d.	Mo_2C (I)	Blank	Mo_2C (I)	Mo_2C (v.w.)	Mo_2C + M_6C
3·83% Mo 0·22% Ta	700	Mo_2C	Mo_2C + M_6C	Mo_2C + M_6C	Mo_2C + M_6C	M_6C	M_6C + Mo_2C	M_6C	M_6C

Key: I = Imperfect structure v.w. = very weak w. = weak n.d. = not determined E.M. = electron microscope E.D. = electron diffraction

The accumulated information on the genesis of V_4C_3 and Mo_2C leaves little doubt that they are for the most part separately nucleated and form initially a coherent precipitate within the ferritic matrix. The habit of the precipitate makes this extremely likely. The controlling factor in both the nucleation of the alloy carbide and its subsequent growth is the diffusion of the alloying element in and into the ferrite.

If the concept of a coherent precipitate is accepted, it becomes easier to discuss the shape of the hardness/tempering curves. In terms of age-hardening theory, the coherency stresses will increase as the size of the coherent precipitate increases. During this period the hardness, or resistance to the movement of dislocations, will increase as the stress fields around the particles become bigger and thus more effective barriers to the movement of dislocations. Eventually, when the local lattice stresses become too large, the particles break away from the ferrite matrix, the stress fields vanish, and the hardness drops rapidly. This rapid drop in hardness was observed in all the steels investigated.

This concept of the secondary-hardening process is supported by the observed effects of cold work. The formation of the secondary-hardening peak is accelerated, just as plastic deformation can accelerate the ageing process in the Al–4%Cu alloy. The modern view is that precipitation is nucleated at dislocations, and that, by providing a much higher density of dislocations by means of cold work, nucleation is hastened. Furthermore, cold work by creating vacancies increases the rate of diffusion which will also accelerate the ageing process.

The most important result of the present investigation is the marked effect on the secondary hardening of small additions of tantalum and niobium. The interpretation of the results is complicated by the fact that in several of the steels the tantalum and niobium formed a small amount of a separate phase, although it had been expected that they would enter

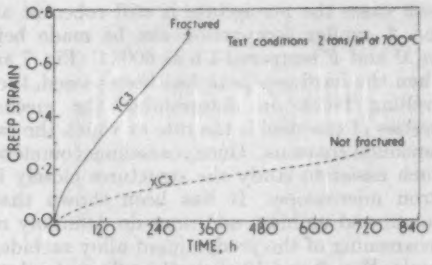


Fig. 21—Creep curves for specimens of two V–Cr steels

entirely into solid solution in the existing alloy carbides. These minor alloying additions appear to have three effects:

(i) Influence on the nucleation of the alloy carbide
(ii) Influence on the growth of the alloy carbide
(iii) Formation of a separate tantalum- or niobium-rich carbide dispersion.

These three factors will be discussed in turn.

One effect of tantalum and niobium was to raise the peak hardness substantially. Now if this peak is associated with the occurrence of a coherent carbide precipitate, then entry into solid solution in the precipitate of tantalum and niobium atoms may well increase the coherency stresses. In addition, if this is accompanied by a decrease in the rate of diffusion of vanadium (or molybdenum) in the matrix due to the presence of tantalum and niobium atoms, then the growth of the coherent precipitate will be impeded and the break away of the precipitate from the matrix will be delayed. So the hardness peak occurs after longer times or at higher temperatures as indicated in Figs. 1, 2, 18, and 19. The electron microscopic evidence is fairly clear on this point; e.g. while the Mo_2C rodlets or needles can just be detected in steel *N* after 1000 h at 500° C (Fig. 11), they could not be seen in replicas from steel *P* (tantalum added) after an identical tempering treatment. It is assumed that

Table V

CREEP DATA ON TWO VANADIUM–CHROMIUM STEELS

Specimen	Grain Size dia., mm	Condition of Steel before Test	Creep-test Condition		Remarks
			Tempering prior to Loading	Creep Stress at Temperature	
XC1 (Ta added)	0·03–0·04	4 h 1300° C brine-quenched	50 h 600° C	9 tons/in² at 600° C	Fractured after 15 h. Intergranular fracture
YC1	,,	,,	27 h 600° C	,,	Fractured after 29½ h. Intergranular fracture
XC2 (Ta added)	,,	4 h 1300° C brine-quenched + 5 h 700° C air-cooled	25 h 600° C	,,	Fractured after 66½ h. Intergranular fracture
YC2	,,	,,	,,	,,	Fractured after 2 h. Intergranular fracture
XC3 (Ta added)	,,	4 h 1300° C brine-quenched + 5 h 700° C air-cooled	96 h 700° C	2 tons/in² at 700° C	Not fractured after 720 h
YC3	,,	,,	24 h 650 °C + 5 h 700° C	,,	Fractured after 308 h. Intergranular fracture

in both cases the precipitate is still coherent at this stage. A similar comparison can be made between steels *M* and *F* tempered 1 h at 600° C (Fig. 7 and 8).

When the hardness peak has been passed, then the controlling factor in determining the mechanical properties of the steel is the rate at which the carbide dispersion(s) coarsens. Once coarsening commences, it is much easier to study the structures closely in the electron microscope. It has been shown that the tantalum and niobium additions do definitely reduce the coarsening of the predominant alloy carbide. For example, Figs. 9 and 10 show this effect clearly. This can be explained by assuming that tantalum (or niobium) in solid solution both in the carbide and the ferrite reduces the rate of diffusion of vanadium, and consequently slows down the rate at which the smaller vanadium carbide particles can dissolve and the larger ones grow.

This interpretation is, of course, complicated by the fact that a separate tantalum (or niobium) carbide phase was detected in several of the steels. While it is unlikely that these phases would nucleate at the same time as the primary alloy carbides, there is no doubt that when they do nucleate they influence the properties of the steel. So in this way they may well account for part of the higher hardness in the over-aged condition of steels containing tantalum or niobium than those without. However, it should be pointed out that this increased resistance to softening was also possessed by steel *S*, a vanadium steel with only 0·05% Ta, which as far as we could determine did not precipitate a tantalum-rich carbide. This improvement in properties could thus only be attributed to tantalum in solid solution in V_4C_3 and/or in the ferrite.

While we do not attach too much importance to the few creep-test results described, they do indicate that the substantial changes in hardness, measured at room temperature, caused by the tantalum and niobium additions, are accompanied by a marked improvement in the resistance to plastic flow under creep conditions at temperatures in the range 600–700° C. We feel that much progress in the understanding of creep-resistant alloys can come from further studies where the carbide phase is deliberately and systematically modified.

Acknowledgments

We are indebted to our colleagues, in particular Professor A. G. Quarrell, Dr. R. G. Ward, and Dr. R. Smith, for their co-operation and helpful discussions.

Our thanks are also due to Dr. T. P. Hughes and Dr. J. Menter for occasional use of the Siemens electron microscope at the Tube Investments Research Laboratory, Hinxton Hall, and to Mr. F. H. Saniter and Mr. P. Murray for providing facilities and carrying out creep tests on several specimens at the Swinden Laboratories of the United Steel Companies Ltd. We wish also to thank Mr. K. Speight of the British Iron and Steel Research Association for the chemical analyses of the steels used.

One of us (A.K.S.) gratefully acknowledges financial support from the Government of West Bengal.

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Letters to the Editor

Chromic Oxide for Metallographic Polishing

CHROMIC OXIDE is sometimes used for the final metallographic polishing of steels and the harder of the non-ferrous alloys, coarse alumina or diamond dust being used for rough polishing. The chromic oxide is commonly prepared by the ignition of ammonium dichromate. Even when care is taken over cleanliness during preparation, it has been found in this laboratory that the resulting powder is often somewhat gritty and the high degree of polish required for photomicrography can be obtained only with difficulty. A similar difficulty was obtained with a sample of a commercial polishing powder. It is the purpose of this letter to describe an improved method of preparation.

Ammonium dichromate ignited in a suitable vessel by local heating with a bunsen burner until the reaction proceeds spontaneously produces a voluminous powder which is dark-green in general colour. Closer examination shows that the product is a mixture of different particles, some bright-green and others black. Small amounts of the two types of particles can be separated mechanically, and by rubbing with the finger it is clear that the green particles are soft and smooth while the black ones are hard and gritty.

The thermal decomposition of ammonium dichromate has been studied by E. H. Harbard and A. King (*J. Chem. Soc.*, 1938, p. 955). They found that the black particles were a non-stoichiometric oxide which contained more oxygen than the green oxide, Cr_2O_3, and was very stable on heating. Treatment in hydrogen at 800° C for 20 h was necessary to reduce the black oxide to the green one.

In consequence, the chromic-oxide polishing powder is now made in this laboratory by ignition of dichromate to form the mixed oxides as before, but instead of washing to remove unburnt dichromate, which is a tedious process, the powder is heated in hydrogen at 800° C for 20 h to remove the undesirable oxide and to burn off any remaining dichromate. The resulting powder is bright-green, very soft, and produces an excellent polished finish on steels and hard non-ferrous alloys.

The work described above has been carried out as part of the General Research Programme of the National Physical Laboratory and this letter is published by permission of the Director of the Laboratory.

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Teddington, Middlesex.

4th November, 1957

Removal of Small Amounts of Nitrogen from Molten Iron

THE METHOD adopted in the Metallurgy Division of the National Physical Laboratory for producing 25-lb ingots of high-purity (99·97%) iron has been described by Hopkins *et al.* (*J.I.S.I.*, 1951, vol. 168, pp. 377–382). The gaseous impurities oxygen (0·20%) and nitrogen (0·01%) in an air-melted ingot were reduced in amount by circulating dry hydrogen for 2–3 h over the molten iron held at 1550–1560° C in an induction furnace enclosed in a steel tank of approximately 55 ft³ capacity. In the hydrogen circulating train there were drying towers and a tube heated to 600° C containing magnesium turnings. As reported by Hopkins *et al.*, the final oxygen and nitrogen contents of the iron were both between 0·001% and 0·002%. The average figure for the nitrogen content of twenty-one 25-lb melts taken at random was 0·0011%.

When the scale of melting was doubled, the volume of the steel tank remaining the same, it was noted that the nitrogen content of the iron was higher, the average of the first twelve 50-lb melts being 0·0016%. About the same time it was demonstrated that magnesium at 600° C was ineffective in removing small proportions of nitrogen from hydrogen. Calculation from available thermochemical data showed that the percentage of nitrogen in iron at 1550° C in equilibrium with a pressure of $\frac{1}{4}$ mm Hg of nitrogen was 0·0012%. The nitrogen pressure in the hydrogen circulating at N.T.P. resulting from the removal of 0·01% N_2 from the 25 lb of oxidized iron would be approximately $\frac{1}{4}$ mm Hg, and twice this pressure when 50 lb of iron are melted. In addition, the cylinder hydrogen used could, according to the suppliers, contain up to 0·05 vol.-% nitrogen as an impurity. This is equivalent to $\frac{1}{4}$ mm Hg of nitrogen. Thus it would appear that the nitrogen content of the iron could not be further reduced without modifying the technique of purification. This was most simply done by pumping out the hydrogen from the tank and replacing with fresh cylinder hydrogen containing a maximum of 0·05 vol.-% nitrogen. The nitrogen content of molten iron at 1550° C in equilibrium with this pressure of nitrogen ($\frac{1}{4}$ mm Hg) is 0·0009%. The average nitrogen content of twenty-six 50-lb melts of iron treated in this way was 0·0008%, indicating that the cylinder hydrogen contained approximately the maximum amount of nitrogen specified by the makers. Further reduction of the nitrogen content of the iron will depend on the availability of still purer hydrogen.

This note, which deals with part of the General Research Programme of the National Physical Laboratory, is published by permission of the Director of the Laboratory.

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6th November, 1957

Magnetic Analysis of Ferromagnetic Inclusions Found in 18/8 Stainless Steel

AUSTENITIC STAINLESS STEEL can sometimes contain ferromagnetic inclusions, such as ferrite, oxides, etc. In the present study, these inclusions found in a cold-rolled plate were investigated by electron diffraction.

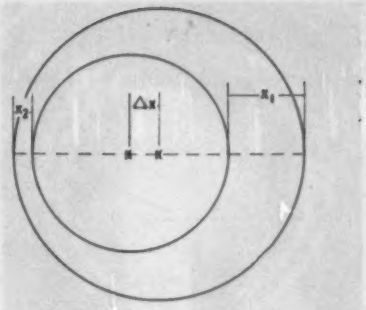


Fig. 1—Illustration of the ring eccentricity for calculation

The path of an electron beam is deflected by a magnetic field as a result of the Lorentz effect. This phenomenon is observable in an electron-diffraction pattern obtained from ferromagnetic substance.

The edge of a wedge-shaped test piece (10 mm × 10 mm × 1 mm) of stainless steel, finished by mechanical and electrolytic polishing, was used.[1] Figure 2*a* was obtained from the edge of the specimen, and from a gold foil, by means of double exposure. In the preparation of Fig. 2*a*, the wavelength of the applied electron beam, as well as the position of the photographic plate, was kept fixed. It should be noted that the diffraction rings characteristic of the test piece, and those of gold, are *not concentric*, and that the photograph is optically enlarged three times in order to emphasize this ring eccentricity. A sketch of Fig. 2*a* is given in Fig. 2*b*, where the principal rings are assigned to gold *A* and to the specimen *S*. The rings characteristic of the specimen coincide with those of the face-centred austenitic lattice ($a_o = 3·52$Å) and with those of the body-centred ferritic lattice ($a_o = 2·88$Å). The (111) ring of the former is indistinguishable from the (110) ring of the latter. There is a possibility of the existence of ferromagnetic oxides and carbides here, because they have interplanar spacings approximately equal to those of the austenitic and ferritic lattices.

Figure 3*a* was obtained from non-ferromagnetic aluminium oxide (bohmite), and from the gold foil, by the same procedure as for Fig. 2. All diffraction rings are concentric, because there is no Lorentz effect. Figure 3*a* corresponds to the blank test for the present magnetic analysis. In Fig. 3*b* the principal rings are assigned to gold *A* and to aluminium oxide *O*.

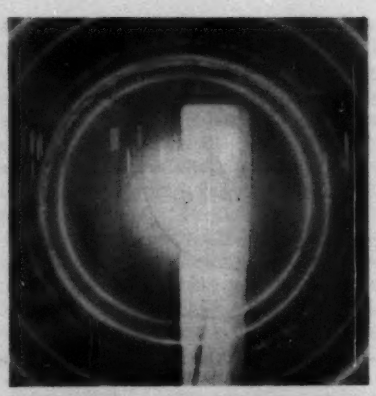
Figure 4*a* was obtained from the edge of a wedge-shaped test piece of nickel (10 mm × 10 mm × 1 mm), and from a gold foil, by the same process as for Figs. 2 and 3. It is noticeable that the ring eccentricity recognizable in Fig. 4*a* is larger than that in Fig. 2*a*. In Fig. 4*b* the principal rings are assigned to gold *A* and to nickel *N*.

It was possible to estimate the quantity of the ferromagnetic substances found in the specimen. Figure 1 illustrates the eccentricity of the diffraction rings for calculation. The deflection Δx of the electron beam caused by the magnetic field H is given by an equation:

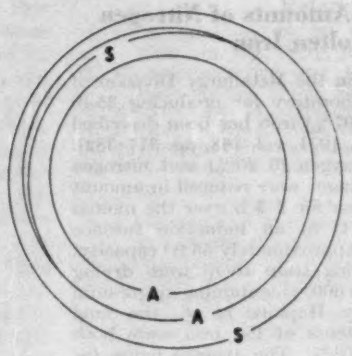
$$\Delta x = \frac{e}{m}\frac{lL}{v} \cdot H$$

or

$$\Delta x = \frac{elL\lambda}{h} \cdot H \quad \text{.....(1)}$$



(a)



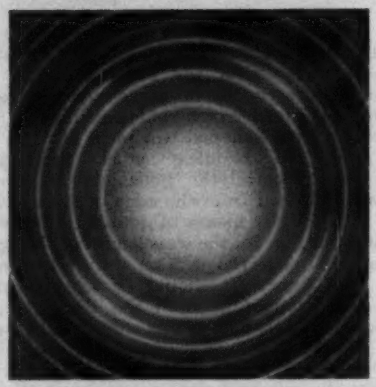
(b)

Wavelength: 0·0298 Å
Camera length: 495 mm

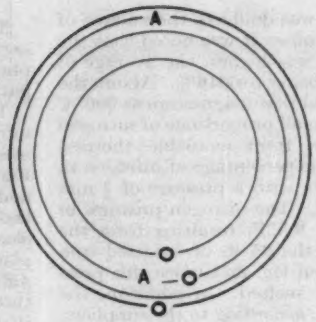
Fig. 2 — (a) Diffraction patterns obtained from stainless steel and from gold by double exposure. The rings are eccentric owing to the Lorentz effect × 3

S = specimen; *A* = gold

(b) Sketch of Fig. 2a



(a)

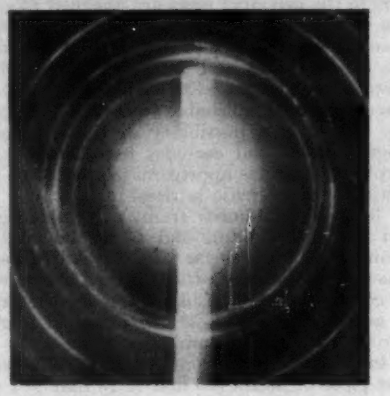


(b)

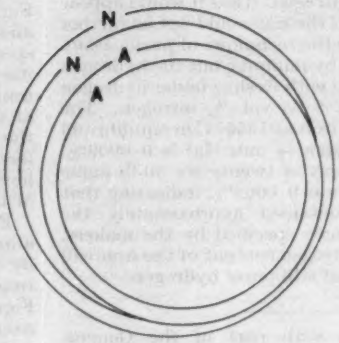
Fig. 3—(a) Aluminium oxide and gold. The rings are concentric and there is no Lorentz effect

O = aluminium oxide; *A* = gold

(b) Sketch of Fig. 3a



(a)



(b)

Wavelength: 0·0294 Å

Fig. 4—(a) Nickel and gold (Lorentz effect)

N = nickel; *A* = gold

(b) Sketch of Fig. 4a

where e = electron charge ($1{\cdot}6 \times 10^{-20}$ e.m.u. (c.g.s.)), m = electron mass, l = the effective range of the magnetic field (about 0·1 mm), L = camera length (495 mm), h = Planck's constant ($6{\cdot}6 \times 10^{-27}$ erg-s), v = electron velocity, and λ = the wavelength of the electron beam

In Fig. 2, according to Fig. 1, we measure

$$\Delta x = (x_1 - x_2)/2 = 0{\cdot}16 \text{ mm}$$

and

$$\lambda = 0{\cdot}0298\text{Å}$$

From equation (1) we get

$$H \simeq 40 \text{ G.}$$

In Fig. 4 we measure

$$\Delta x = 0{\cdot}87 \text{ mm}$$

and

$$\lambda = 0{\cdot}0294\text{Å}$$

Therefore

$$H \simeq 240 \text{ G.}$$

This H value agrees approximately with the known residual magnetization of nickel. The quantity of the ferromagnetic inclusions found in the test piece is thus estimated as compared with nickel.

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14th October, 1957

1. S. YAMAGUCHI: *J. Appl. Phys.*, 1954, vol. 25, p. 811.

Corrigenda

Certain revisions were made by the authors to several illustrations in the paper by G. T. van Rooyen and W. A. Backofen entitled " Friction in Cold Rolling " (*Journal*, 1957, vol. 186, June, pp. 235–244), but these were unfortunately lost in transit from the U.S.A.

The revised versions of Figs. 1, 6, 9 (part), and 15 are given below. The following corrections to Figs. 10 and 11 should also be noted:

Figure 10: The constant value of the ratio (surface shear stress)/(normal stress) in the upper part of the figure should be reduced from the value given to a level of 0·1.

Figure 11: In the upper part of the figure the curve relating (surface shear stress)/(normal stress) to roll contact angle should be lowered so that the peak value of 0·28 shown is reduced to the value of 0·15.

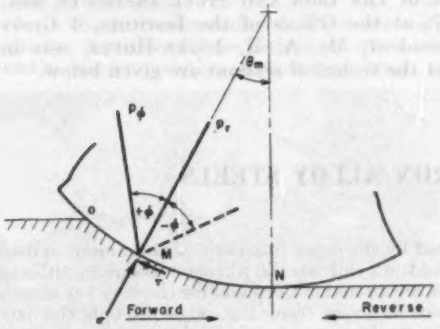


Fig. 1—Location of pins in rolls

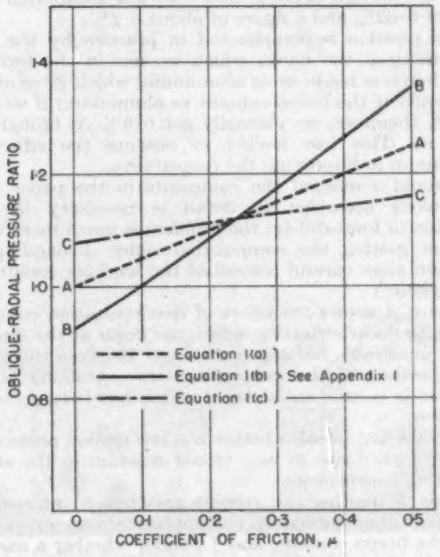


Fig. 6—Correction curves for friction

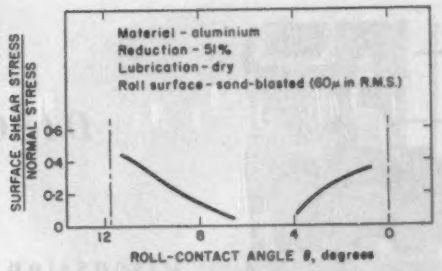

Material - aluminium
Reduction - 51%
Lubrication - dry
Roll surface - sand-blasted (60μ in R.M.S.)
SURFACE SHEAR STRESS / NORMAL STRESS
ROLL-CONTACT ANGLE θ, degrees

Fig. 9—Ratio of surface shear stress to normal stress with sand-blasted roll

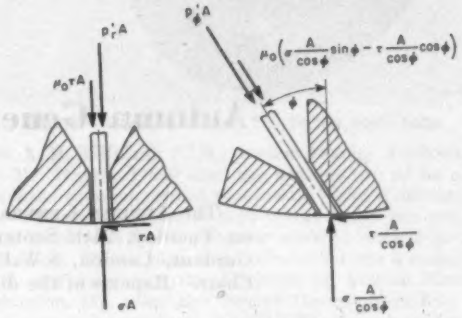


Fig. 15—Forces acting on pins

Siemens Exhibition

A small exhibition presenting the life and work of Sir William Siemens opened at the Science Museum on 10th March, 1958. It has been prepared in collaboration with Siemens Edison Swan Ltd., and is based upon exhibits collected together for display at the Central Hall, Westminster, on the occasion of the Siemens Brothers Centenary Lecture on 5th March.

Charles William Siemens was an outstanding figure in the industrial development of the nineteenth century, combining scientific insight and technical ability with an unusual degree of commercial acumen. He was an acknowledged pioneer of the electrical industry, both on the telegraph and supply sides, and his application of his regenerative furnace to metallurgy made him also a leader of the steelmaking industry.

The exhibition traces his career and achievements in a chronological sequence. The early years, up to his election to the Royal Society, are represented by exhibits relating to his inventions of that period, and to the beginnings of his work with submarine cables. His later work is represented by exhibits dealing with the practice of steel manufacture and with the development of the electrical industry.

The various threads are brought together in a centrepiece which summarizes his achievements and shows modern developments to which his work contributed.

Siemens was President of The Iron and Steel Institute from 1877 to 1879, and was awarded the Bessemer Gold Medal in 1875. It was announced by the President at the Autumn General Meeting, 1957, that the Institute would be celebrating the centenary of the Siemens–Martin steelmaking process in 1963 (see *Journal*, 1957, vol. 187, Nov., p. 240).

DISCUSSION ON PAPERS

Discussion at Meetings · Written Contributions

Autumn General Meeting, 1957

The AUTUMN GENERAL MEETING of THE IRON AND STEEL INSTITUTE was held on Tuesday, 24th September, 1957, at the Offices of the Institute, 4 Grosvenor Gardens, London, S.W.1. The President, Mr. A. H. INGEN-HOUSZ, was in the Chair. Reports of the discussions at the technical sessions are given below.

DISCUSSION ON HIGH-BORON ALLOY STEELS

This discussion was based on the paper by T. H. Middleham, J. R. Rait, and E. W. Colbeck, entitled "**High-boron Alloy Steels,**" which appeared in the September, 1957, issue of the *Journal* (vol. 187, pp. 1–14).

Mr. **T. H. Middleham** (Hadfields Ltd.) presented the paper.

Mr. **G. T. Harris** (William Jessop and Sons Ltd.,): I should like to congratulate the authors on a fascinating piece of work. Nuclear energy has provided many new problems in the field of non-ferrous metallurgy—zirconium, beryllium, niobium, handling of liquid metals, and so on—but it has provided surprisingly few challenges in the ferrous field. I think that the paper under discussion is an example of one of the most interesting of these possibilities which have been so thoroughly explored by Hadfields Ltd.

The question of adding substantial amounts of boron to even the simplest steels raises many problems which have been outlined by Mr. Middleham on behalf of his colleagues. We followed this work with great interest, because for several years we have been working along parallel lines. They have, however, concentrated on mild steel and low-alloy steels, whereas we have been mainly interested in some of the higher-alloy steels, particularly stainless steels.

We agree completely with the findings of Mr. Middleham and his colleagues that in carbon steels the limit of forgeability is with about 4% B under normal conditions. It is interesting that this is about the eutectic composition, and I wonder whether the authors have any comments on the significance of this in relation to forgeability.

They have drawn attention to the interesting effect of aluminium, but I should like to ask how far this is affected by the other functions of aluminium in deoxidation and in tying up the nitrogen, because, although no figures are quoted in the paper for the very low aluminium content, it looks from Fig. 4 as though the level of aluminium necessary is merely that which will tie up the oxygen and the nitrogen. This may not be right, but there are no figures between a very low aluminium content of 0·02% and a figure of about 0·2%.

The position is complicated in practice by the fact that most of the boron which we use in the form of ferro-boron is made using aluminium, which gives about one-tenth of the boron content as aluminium; if we add 3% B, therefore, we normally get 0·3% Al brought in with it. This has tended to obscure the effect of aluminium in improving the forgeability.

I would commend the comments in the paper that meticulous attention to detail is necessary in this question of forgeability; the problem is much more than that of getting the composition right, demanding in addition most careful control of the working conditions throughout.

Figure *A* shows the effect of deboronization comparable with decarburization which can occur at the surface under unsuitable heating conditions. Between the outer oxide scale and the inner structure containing boron eutectic is a substantial layer which has been denuded of boron.

I would like to ask whether the low carbon content of the steel gave rise to any mould reaction in the shell-moulding experiments.

Table V quoting the specific gravities is interesting, but the values quoted do not appear to vary rationally with the boron content, and I wonder whether a careful check has been made to ensure there are no errors due

to porosity. Figure *B* shows a cast tube containing 7% B (higher than any quoted in the paper) and the specific gravity of this material is 7·31.

We were particularly concerned about the very poor corrosion and oxidation resistance of these alloys, and, because they rust so easily, we diverted our attention to the addition of substantial amounts of boron to stainless steel. We discovered that we could add approximately the same percentage of boron to both ferritic and austenitic stainless steels without too drastic an effect on the forgeability and mechanical properties. Both 13% Cr steels and austenitic stainless steels will tolerate about 2·5–3% before becoming unforgeable.

I was disappointed to find that the paper contains no reference to the mechanical properties of these steels, and should be glad of any information on the point. We have determined the mechanical properties of various composition series which may be of interest, and these are given in Table 1.

It will be seen that the addition of boron in mild steel drops the elongation, but not as badly as the authors suggest; even with 3% B there is still 4% elongation, although at 4% B the elongation is less than 1%. With 2% B, whether in mild steel, martensitic, or austenitic stainless, the elongation is about 8%. The extremely high proof stress of the 17–7 austenitic steel is particularly interesting.

Finally, it should be observed that there is some promise that the ductility of these high-boron steels can be improved by the introduction of vacuum melting.

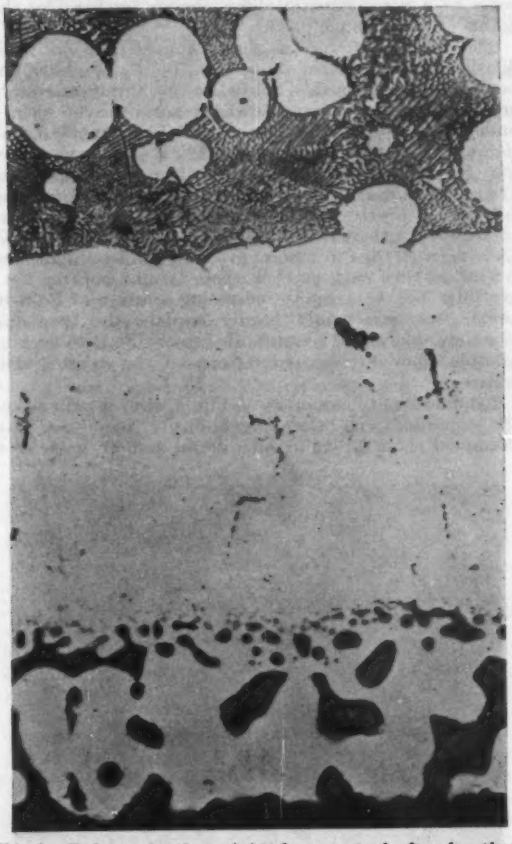


Fig. A—Deboronization of 1% boron steel after heating for 6 h at about 1175° C × 250

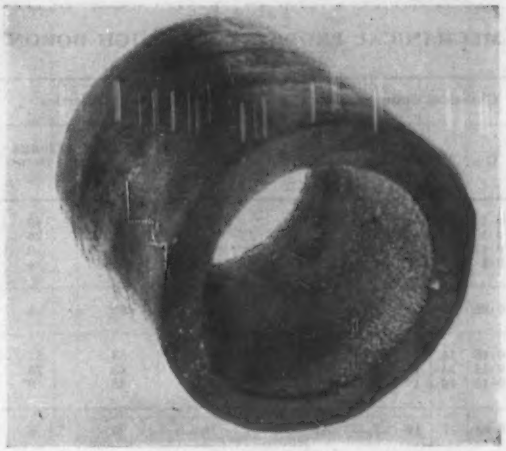


Fig. B—Portion of cast 7% boron steel tube

Dr. **A. B. McIntosh** (U.K. Atomic Energy Authority): Like Mr. Harris, I feel that the authors are to be congratulated on a successful systematic piece of investigation. The development of high-boron alloys has played a significant part in the progress made in nuclear power production. The organization of which I am a member, which was originally the Division of Atomic Energy Production, ten years ago carried the responsibility for the design and construction of BEPO, the experimental pile at Harwell, of the first plutonium producers at Windscale, and, later, of the first power producer at Calder Hall.

In the BEPO reactor the control rods were made of a boron compound in a tube, not, as is said in the paper, of boron steel. But when we came to the design of the Windscale piles, we felt that the need would be best met if we could obtain a steel of the necessary strength containing the necessary neutron-stopping materials and of the desired oxidation resistance. The physicists told us that we had to get at least 2% B into the material.

I approached five of the principal steelmaking companies in the country and, as a result, development work was started in three centre—at Hadfields, of which we have heard an account today, at Jessops, and at Firth Browns.

The development work in each of the centres soon disclosed the very great difficulty in forging these alloys, particularly as the boron content increased. We had hoped to get a bar of steel about 30 ft long, but it was soon apparent that our rigid time schedule would make it difficult to achieve this in time. There were other restrictions which made the development work difficult. We had to avoid excessive weight for the shielding of beta–gamma residual activities, and that meant that we had to cut down to a minimum some of the elements (e.g. manganese) normally found in steel.

In view of the difficulties which we felt would be experienced with oxidation resistance, we raised the question of stainless steel containing boron. At that time Hadfields made a few trial casts, and we soon found that the toughness and impact resistance were likely to be low. In view of the use for which this was required, we could not tolerate the possibility that contamination of the reactor would result if any part of the steels flaked off as a result of fracture, of oxidation, or any other cause. We had such a short time in which to work that we were forced to put bits of boron steel in a stainless-steel tube. This removed one of the sources of contamination of the reactor.

Table 1
MECHANICAL PROPERTIES OF HIGH-BORON STEELS

Chemical Composition, %					Mechanical Properties		
C	Ni	Cr	B	Others	0·1% proof stress, tons/in²	U.T.S., tons/in²	Elongation, %
0·1	—	—	0	—	(7)	19	50
0·1	—	—	1	—	8	27	26
0·1	—	—	2	—	16	37	9
0·1	—	—	3	—	20	49	4
0·05	1	14	2·4	Al 0·6	—	60	5
0·15	14	19	0	Nb 1·5	13·5	38	52
0·15	14	19	1	Nb 1·5	14·4	43	25
0·15	14	19	2	Nb 1·5	18·8	48	8
0·03	7	17	1	Al 1·0	78	95	8

The authors have drawn attention to the very great importance and influence of aluminium. They suggest that this is instrumental in providing the solution to the forging difficulties. In the work at Firth Browns, Dr. Sykes also drew attention to the presence of aluminium, but, because of the limitation of time and other commitments, he was unable to explore its full effect.

As far as forgeability is concerned, Mr. D. A. Oliver advised us as a result of his inquiries that he was of the opinion that we ought to be able to forge this alloy with up to about 3% or 4% B. Again, time did not allow this work to be fully developed.

It was not until we came to Calder Hall that we returned to this. In Calder Hall the engineers wished to suspend the control rods from cables and therefore wanted to reduce the weight. By this time we had learned that the effect of boron is largely confined to the surface, so that to all intents and purposes the middle is unnecessary weight. That was why we raised the possibility of the use of tubes in Calder Hall. In view of other factors, however, the boron content had to be increased.

Again the relevant work was undertaken both at Hadfields and at Jessops. Jessops concentrated on stainless steels and Hadfields continued the line with which they had had a great deal of success. The present paper records the successful outcome of their systematic investigation.

The requirements for which we had asked, a minimum of 5% B, were not achieved in the time available, but it is pleasing to note that with wrought material, according to the paper, the permissible amount is now nearly 5%. Mr. Harris gave a higher figure; with the cast material it exceeds 5%.

This is one of the first programmes aimed at the development of shielding alloys. To some people there is more attraction in other sides of atomic energy such as in the fission zone and so the development of these alloys sometimes does not receive the attention it merits. But there is a rewarding field of investigation here because, particularly with nuclear power propulsion, we are faced with a dominant need to develop alloys which will cut down the mass required for shielding. These alloys will be wanted in the form of sheets, plates, rods, bars, and tubes, and in many cases there will also be a great advantage in stainless properties.

Mr. **J. E. Russell** (English Steel Corporation Ltd.): I should also like to praise this extremely interesting paper, which is an introduction to the study of these higher-boron steels, as distinct from those to which boron is added merely for hardenability purposes.

Our work on these steels has been on a rather limited scale, but, where it overlaps that published in the paper, we are in broad agreement with the authors' results.

In Figs. 5*a* and *b*, the authors show a microstructure of the 4·20% B steels at magnifications of 50 and 500. We were struck by the surprising coarseness of these structures. We have also made this composition and the general microstructure was similar, but the size of the constituents was much finer: nearly 50 times smaller. Our alloys were made in a 2-in. square ingot, and examined in the as-cast condition. It would be interesting to know the origin and condition of the microstructures given in the photograph.

The authors say that they found very little effect with heat-treatment, except a slight granulation of the structure at about 1100° C. We have found that by what might be called a 'sub-critical' treatment (about 850° C, a little below the alpha→gamma change as shown on the best of the three diagrams) the eutectic becomes very much more broken up and coagulated into an irregular mixture of Fe_2B and ferrite, as illustrated in Figs. *C* and *D*. There is a slight softening from about 460 to about 430 D.P.N.

The equilibrium diagram of these alloys is still very confused in the lower temperature ranges. Both the Hannensen and the Tschischewsky and Herdt diagrams identify the magnetic change at 760–770° C with an actual phase change, but it is probably simply a magnetic to a non-magnetic alpha change, rather like the alpha → beta change in pure iron.

The authors found a slight contraction on their dilation curve, over the range 500–700° C. We have not been able to confirm this, but below 700° C there certainly are constitutional changes which are not yet clearly understood. For example, a curve of the magnetic induction against temperature for a 4·3% B alloy is shown in Fig. *E*, with one for a low-carbon iron for comparison. The curve shows a small hump at about 100° C. and then falls off to nearly half the room-temperature value at about 600° C; thereafter it falls steeply to zero at 770° C, agreeing with the Curie point given by Muller and others.

The authors suggest that their 'slight contraction' over 500–700° C is due to increasing solution of Fe_2B in alpha, but this would hardly explain the magnetic effect, as this would require much more Fe_2B to go into solution than is indicated on any of the existing diagrams.

I should like to comment on Fig. 4, showing the effect of aluminium on the forgeability. We have not examined these alloys in such detail and we have been

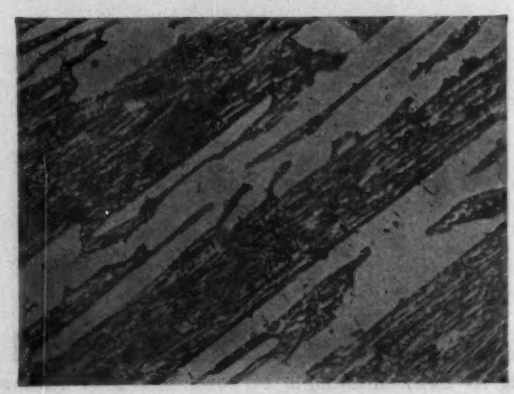


Fig. C—4·3% boron steel as-cast × 500

more concerned with cast material than forged products, but we have the impression that the curve shown in Fig. 4 is not merely the boundary of forgeability but is also that of room-temperature brittleness. I wonder whether the authors would agree with this conclusion, since it is of more interest to users than the question of forgeability. Incidentally, it would be interesting to know if the authors have been able to move the nose of this curve to higher boron contents by the use of other alloying elements.

I should like to ask the authors if they could give any information on how these rods behaved in service? It is well known that in the neutron flux of a reactor the boron will disintegrate and give off various gases. What has been the effect on the steel of this gas evolution? What does it look like after a few years in a reactor?

Mr. **E. Fanthorpe** (A.E.I.–John Thompson Nuclear Energy Co., Ltd.): My main concern is with the possibility of providing a boron-steel lining inside a pressure vessel of the Calder Hall type. In this case it is not only the fact that boron has a high thermal neutron cross-section but also the fact that this is a high cross-section for the n, α reaction and therefore the resulting secondary radiation is easily captured.

There are four possible advantages in using the boron steel in this way.

(i) It would increase the possibilities of inspecting the pressure vessel when the reactor is shut down. A reduction to about 10–20% of the dose rate outside the pressure vessel can be obtained by using this lining as an inner lining
(ii) The heating effect of the nuclear radiation on the pressure vessel can be reduced to about 10–20% of that without a lining
(iii) We can reduce the heating effect on the concrete of the biological shield by about 20–30%
(iv) We can reduce the thickness of the concrete very slightly.

Those are the advantages from the shielding point of view. There are a number of disadvantages. The first is the difficulty of supporting the boron-steel liner. Secondly, there must be no possibility of the escape of boron into the gas stream, and therefore we need to clad the boron-steel liner.

I know very little about the question of control rods, but one or two points have occurred to me. The first concerns gas production, which Mr. Russell mentioned. I, too, would like to know whether helium production is of any importance, especially in high-flux reactors. The second question is probably one of economics. The figures which Mr. Harris produced showed that with 1% B we get very good mechanical properties. If this were 1% ^{10}B,

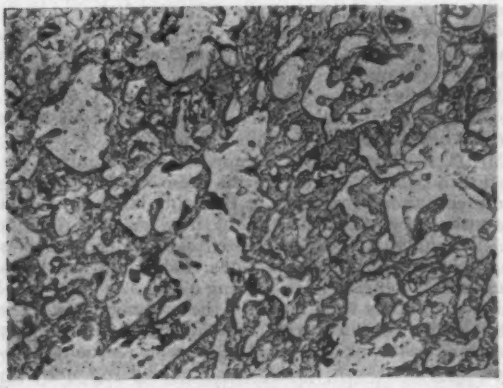


Fig. D—As Fig. C, but after annealing at 850° C × 500

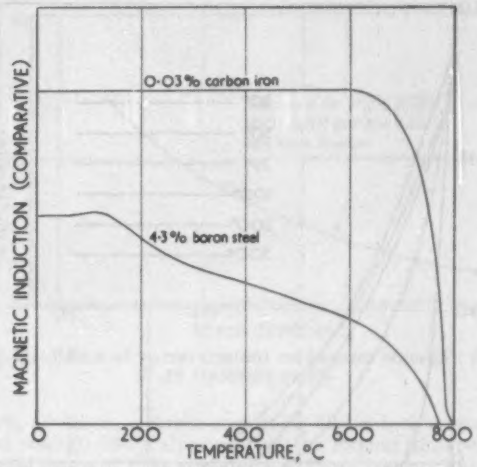


Fig. E—Variation of magnetic induction with temperature

presumably there would be the same mechanical properties with effectively five times as much neutron absorption, because ^{10}B is the important isotope in this matter.

Lastly, a question which is probably not quite appropriate to the discussion: there are probably other materials of high neutron cross-section which could be used. Some of the rare earth materials come to mind. I presume that the use of these is a question of economics.

Mr. **A. Prince** (G.E.C. Atomic Energy Division): There are one or two points I should like to raise with Mr. Middleham. The first concerns the welding of the sandwich plates. He showed an etched section of a butt weld between two sandwich plates. Could he say how he made this weld? Presumably, to avoid boron pick-up when welding the mild-steel layer, the current must be a minimum. Apparently he has not managed to fuse the mild steel on the section shown. Could he tell us whether, if we increase the current, there is a possibility of getting an admixture of boron into the mild steel, thus defeating the objective, when we have to weld one section of sandwich plate to another?

The next comment concerns the phase diagrams. The authors said that their alpha → gamma change disappears in any content of boron steel whenever they add appreciable amounts of aluminium. I should like to know whether Mr. Middleham thinks that that is explained by the peritectoid in the iron–boron system disappearing with the aluminium contents studied because of the transition within the ternary of the limited α-field to an open α-field.

Again, in the summary of the constitutional work, the authors have omitted the work of Nicholson (*Trans. A.I.M.M.E.*, 1954, vol. 200, pp. 185–190), probably the most accurate work on solubility in the α and γ regions to date. Busby, Warga, and Wells (*Ibid.*, 1953, vol. 197, pp. 1463–1468) also studied the solubility of boron in α- and γ-iron by diffusion experiments. As the authors state, Wever and Mueller's work should now no longer be considered the best reference for solubility data.

Two errors have crept into the paper. McBride and co-workers (*Trans. A.S.M.*, 1954, vol. 46, pp. 499–520) found the solubility of boron in α-iron to be less than 0·0004% at 710° C and *not* less than 0·004%. The atomic percentages in Fig. 3 also appear to be incorrect.

Mr. **L. M. Wyatt** (U.K. Atomic Energy Authority): My colleague Dr. McIntosh has dealt with the history of the original manufacture of boron steel for the Authority. I

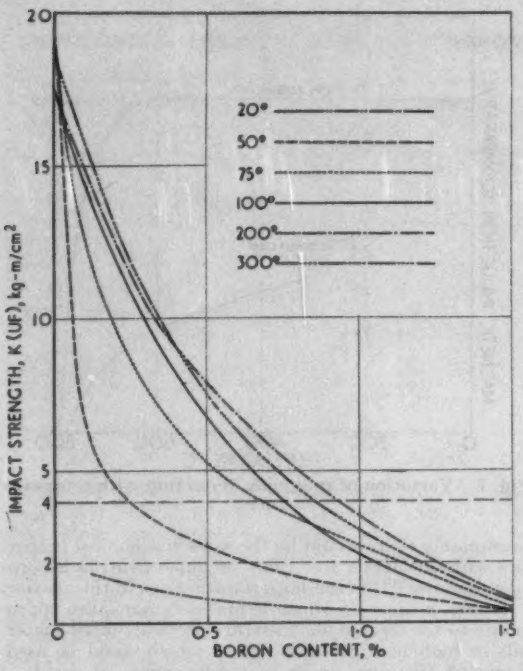


Fig. F—Effect of boron content on impact strength for non-stainless steels

would like to show why such a material was chosen, its disadvantages, and something of the lines along which control-rod design may go in the future.

In designing an atomic pile it is essential to provide as large an area as possible of the material which will stop and absorb neutrons. In addition, as a contradictory requirement, the control rod must be as small as possible to save space in the pile. That is the kind of difficulty which is often met in atomic energy work. It must not be too heavy, because it must sometimes be set in motion rapidly and stopped quickly. It should have the mechanical strength to withstand the inertia forces which this stopping and starting generate.

The materials which fulfil all these contradictory requirements are gadolinium, europium, and samarium, three expensive rare earth metals, and cadmium, which melts at a low temperature. In fact, alloys of cadmium, silver, and indium are being developed, and they may be competitors of boron, but obviously an alloy containing silver will be comparatively expensive. Lithium and hafnium might be used, but hafnium can only be obtained in conjunction with large quantities of zirconium, as in the U.S.A. Out of these rather unpromising materials a sound engineering material must be produced, and boron is by far the cheapest and mostly readily available. The obvious thing to use, therefore, was boron steel.

Hadfields and the other firms working on this found that 4% B steel was about the best that one could get. As Dr. McIntosh hinted, 5% B steel is required only in a comparatively thin material. A quarter of an inch of it will stop all the neutrons that come into its path and it is fairly easy to fit into the reactor a material of this thickness. For a water reactor a thinner section would be required which would lead to difficulties. You could probably get over this by using enriched boron. It is possible to enrich the outside, and the process, compared with other diffusion processes, is not too expensive.

This would be fine for the bulk of the control rods. If you design a reactor which is to have a control rod right through it while it is working, it is a bad reactor, because the control rod is absorbing expensive materials. Someone pointed out that boron with neutrons produces α-particles which become helium. If we think of the tips of the Calder Hall type of control rods, with 5% B, and make some slightly pessimistic assumptions as to the amount of radiation they will have during their life, we find that for 10% burn-out of boron 6 cm³ of helium will be produced for every 1 cm³ of the original material. We have not burned up boron steel to this extent yet, but various calculations which we have made on fuel elements show that the boron steel would be getting slightly unhappy about this burn-out. It might tend to swell or break. The α-particles damage the lattice and make it very brittle at low temperatures. For the higher-rated reactors of the future, 10% burn-up at the tips will occur much earlier in the reactor's life and they will need changing somewhere between 1 and 4 years. In addition, space will be more limited. It is possible that the reactor designer can accommodate this. If so, there will be a very good demand for boron steel.

If not, and in particular if lighter control rods are needed, other materials will be required. The most likely type of material would appear to be dispersions such as boron carbide in steel or copper, or gadolinium oxide in steel or nickel which would presumably have to be made by powder methods. By this means considerably higher concentrations of absorber and, it is hoped, considerably higher burn-ups could be obtained.

Mr. **H. L. Parker** (Rolls Royce Ltd.): I was interested when Mr. Harris mentioned the possibility of vacuum melting as a means of obtaining improved ductility.

A recent paper from the Argonne National Laboratory (A.N.L. 5561) reports on a vacuum-melted 18–8 steel containing 2% B. Elongations of 13–15% at room temperature are claimed.

Mr. **G. E. Darwin** (Babcock and Wilcox Ltd.): I have a question addressed not so much to the authors as to Mr. Wyatt. He gave some figures for the swelling to be expected. Is this not very temperature-dependent? If the temperature rises, the helium produced in the boron will diffuse more rapidly and form bubbles, and you will get swelling. In a water-cooled reactor, where the temperatures are low, you can accept very big burn-ups. As the temperatures of reactors rise, you get more swelling and you are only able to stand a smaller burn-up.

Mr. **Wyatt:** It is difficult to answer a question like that. Water-cooled reactors run at about 260° C and our reactors run at about 400° C. The boron gets a little hotter in both cases; I should think by the same amount. As far as the properties of steel and diffusion are concerned, I do not think that the difference between those two temperatures would have a very great effect. If you reach the 700–800° C range, I should expect the boron steel to swell much more quickly.

Mr. **Darwin:** American work (Volovage: U.S.A.E.C. Report KAPL 1403) shows a marked effect on boron carbide heated to 550° C. It fell to pieces.

Mr. **D. A. Oliver** (B.S.A. Group Research Centre): Dr. McIntosh pointed out that, with these highly absorbing boron-containing materials in thin tubular form, it was the outer layers which did most of the work. The thought which occurs to me concerns the extent to which ductility is vital in annular tubular sections. I should like to know what are the objections to putting a high-boron material inside a stainless tube made in the ordinary way. The tube might be filled with annular rings of a highly absorbing material, which could be cast, as the authors have indicated, or might be moulded by powder-metallurgy methods and sintered, or even extruded and

sintered. If any light could be thrown on the current requirements of nuclear power station engineers it would be most helpful.

The **Chairman** (Dr. H. H. Burton, C.B.E.): Many figures have been quoted for the elongation of various boron-containing materials, which I assume refer to the material before it has been subjected to irradiation. Surely what is more important is the rate of decay of that elongation. If these materials decay at different rates, that should be taken into consideration. If, after six or twelve months' use, most of these materials have only half, or less than half, the elongation with which they started, surely it is unrealistic to specify the desirable properties by the methods indicated today. What we want is a material in which the rate of decay in ductility is the least, not necessarily one which starts with the highest ductility, because if for half the life you have an elongation in the material very much less than that with which you start, the original figure is somewhat unrealistic.

Dr. **McIntosh**: There is some confusion in respect to ductility. We did not specify ductility figures, although no responsible engineer would use a control rod if there was any possibility that some of the material could detach itself and poison the reactor. The practice of sheathing pieces of boron steel ensures that the neutron-stopping material is contained. The Chairman is quite correct in saying that if we were going to be interested in ductility we should have to take into account the change of ductility as a result of irradiation.

CORRESPONDENCE

Monsieur **J. Hochmann** and Monsieur **A. Desestret** (Direction des Recherches de la Compagnie des Ateliers et Forges de la Loire, Unieux, France) wrote: We should like to congratulate the authors of this excellent paper; it is the first time, as far as we know, that a systematic study of high-boron steels has been published.

Concerning the maximum boron content which can be present in a hot-workable steel, these laboratories investigated whether the limits accepted up to now (about 2·0%) could be extended by the addition of gamma- or alpha-stabilizing elements. The aim of these additions was to obtain a single-phase structure during high-temperature treatment, be it pure austenite or ferrite, avoiding the eventual co-existence of these two phases. Test forgings showed that an addition of 5% of nickel, which has the effect of lowering the transformation point and making the austenite more stable, does not produce a favourable effect. On the other hand, the addition of

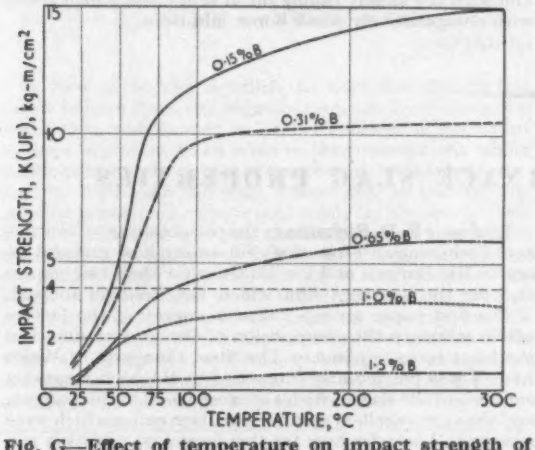


Fig. G—Effect of temperature on impact strength of mild steels containing boron

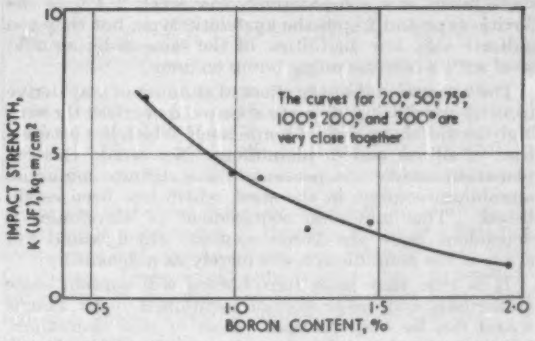


Fig. H—Effect of boron content on impact strength for 17–15 stainless steels

2–4% of silicon, a ferrite-stabilizing element, to a dead-mild steel (0·050% C) permitted the forging of experimental ingots of 15 kg containing 4·2% of boron. Satisfactory forging conditions are severely restricted: the initial temperature must be between 1020° and 1070° C, and it is necessary to finish forging above 900° C.

We have also studied the impact strength of boron steels at different temperatures between 20° and 300° C. We examined low-carbon (< 0·050%) boron steels containing no other special elements, and stainless steels containing 17% Cr and 15% Ni. The curves in Figs. *F–H* summarize the results obtained. The impact strength of the mild steels at room temperature falls below the figure of 2 kg-m/cm² (French impact specimen)*, even with a boron content of 0·12%; this value decreases further when the boron content is increased, falling to a negligible value for a boron content of 0·4%. At higher temperatures a difference in behaviour is observed between the steels of different boron content, the impact value increasing significantly with temperature for boron contents of less than 1%, while there is no improvement with a content of 1·5% (Fig. *F*).

Figure *G* indicates clearly the existence of a transition temperature occurring at about 50° C for the steels containing up to 1% boron; on the other hand, with 1·5% boron, an increase in temperature does not improve the impact value.

In the case of the austenitic stainless 17–15 steels (C < 0·050%), the impact value at 20° C is quite high (7 kg-m/cm² for a boron content of 0·65% and 4 kg-m/cm² with 1% boron). Even with a boron content of 1·5% the impact value is still 2·5 kg-m/cm². Contrary to what was observed in the case of the mild steels, an increase in temperature from 20° to 300° C does not produce an appreciable effect on the impact value.

It seems, in the light of these experiments, that the impact brittleness of a notched test-piece of boron steel tested at 20° C is, in the case of mild steels, a characteristic of the solid solution; it exists even in the absence of precipitation rich in borides. In the case of austenitic stainless steels, this brittleness only appears in the presence of large inclusions of borides; the solid solution itself is not brittle.

AUTHORS' WRITTEN REPLY

The **authors** wrote: We thank Mr. Harris for his general confirmation of some of our findings, and for the information about higher-alloyed stainless steels containing boron. It is a pity that the boron contents of

*The unified French (UF) specimen is a rectangular bar 10 × 10 × 55 mm³ with a cylindrical notch 5 mm deep × 1 mm radius in the centre of the longest side.

these finish at a comparatively low level, 2·4% in the ferritic type and 2% in the austenitic type, but they too indicate very low ductilities, of the same order as mild steel with a corresponding boron content.

The suggestion that the effect of aluminium may derive from its deoxidizing property appears to overlook the very high deoxidizing power of boron itself, which lies between that of silicon and of aluminium. Nor would this explanation satisfy the necessity for a definite minimum aluminium content in the steel, which has been established. This minimum requirement of aluminium is dependent upon the boron content, which would not apply if the aluminium acted merely as a deoxidizer.

It is true that most ferro-borons will contain some aluminium, and the proportion mentioned by Mr. Harris would not be very unusual. Most of this aluminium, however, can be and is lost during melting, as many examples in the paper will show. The aluminium content is controlled by deliberate aluminium additions and is not merely a residual. There is thus no obscuring of the effect of aluminium: the effect is clearly demonstrated.

The deboronization shown by Mr. Harris is an effect we have not experienced in processing large quantities of these steels. The unsuitable heating conditions, unspecified, causing it can therefore easily be avoided.

In spite of the low carbon content no mould reaction occurs with these steels in shell moulding, such as is often experienced with ordinary low-carbon steels. This is probably because of the very low casting temperatures which are permissible.

We are indebted to Dr. McIntosh for his admirable survey of the history of the development of materials for neutron absorption and shielding.

Though in general agreement, Mr. Russell's experience differs from ours in one or two respects. The photomicrographs to which he refers are of steels cast in sizes comparable with his, and in the as-cast condition. Without knowing more about his steel it is impossible to explain the difference in coarseness of structure to which he refers. It may be that other casting conditions were very different, or his steel may have contained some element which exercised a nucleating effect. The differences in the indications of our respective dilation studies may also possibly be due to unknown differences in composition. Our tests were done on a Chevenard differential dilatometer under heating rates of 5° C/min. The differential method is extremely sensitive, and slow heating lengthens the range for any phase change.

We are glad to see the additional information on magnetic induction mentioned by Mr. Russell, which would seem to imply that some other change besides solution of Fe_2B in alpha is occurring in the range 500–700° C. Some further X-ray investigations have given indications of the presence of a superlattice in the high-Al–high-B range.

We do not agree that the curve of forgeability shown in Fig. 4 also marks the boundary of room-temperature brittleness. There is no sharp demarcation in toughness as the curve is crossed, nor is there any appreciable difference in this property over a wide range of aluminium contents at a given boron level. For information on the effect of exposure to irradiation on these materials we would refer Mr. Russell to Mr. Wyatt's contribution.

The idea mentioned by Mr. Fanthorpe of using a boron-steel lining inside the pressure vessel is one which has arisen previously. Economic grounds may rule out the use of a complete inner lining, but we are currently supplying boron-steel sandwich plates for the internal shielding of those parts of the vessel where inspection and maintenance are most necessary.

We can assure Mr. Prince that there is no real difficulty in making the type of weld he describes, in spite of the impression he gained from the slide. By using a low current the boron pick-up in the mild steel is kept to a minimum, but with good adhesion the first run will always contain some boron, say about 0·1%, picked up from the base boron steel. A second or further runs would generally be necessary, when the boron content at the surface would be lower than 0·01%. We thank Mr. Prince for drawing our attention to the inaccuracies he mentions.

We are indebted to Mr. Wyatt for his discourse on control materials, present and future, and also for his help in answering some of the questions put by other speakers.

The figures quoted by Mr. Parker of the ductility of vacuum-melted 18–8 with 2% B appear to support the general belief that vacuum melting improves ductility.

We are not in a position to furnish data on the ductility of these steels after prolonged irradiation, but we agree with Dr. Burton in stressing the real importance of any property change which occurs during service.

The contribution of MM. Hochmann and Desestret is extremely interesting. We can confirm that nickel has a very limited effect on the forgeability of these boron steels. We are encouraged by much that is confirmatory of our work, and it is to be regretted that obviously a much condensed version of their work has been submitted. The explanation for the brittleness of austenitic stainless steels, which is said to occur only in the presence of large inclusions of borides in a tough matrix, seems not to be in line with the steady falling off in toughness which starts with comparatively small boron additions.

DISCUSSION ON BLAST-FURNACE SLAG PROPERTIES

This discussion was based on the following papers (the dates of publication in the *Journal* are given in parentheses):

"**Influence of Slag Properties on Pig-iron Composition,**" *by A. J. Burgess and B. G. Baldwin* (1957, vol. 186, June, pp. 227–235).

"**The Liquidus and High-temperature Properties of Blast-furnace Slags,**" *by B. G. Baldwin* (1957, vol. 186, Aug., pp. 377–395).

Mr. **A. J. Burgess** presented the first paper and Dr. **B. G. Baldwin** the second.

Professor **F. D. Richardson** (Imperial College of Science and Technology): First of all let me say how grateful we are to Mr. Burgess and Dr. Baldwin for their two papers and for the excellent film which Dr. Baldwin showed.

The first paper gives a valuable survey of the factors which influence the composition of the iron produced in the blast-furnace plant of The Steel Company of Wales Ltd. I was particularly interested in the high magnesia contents of the slags, which are exceptional in this respect, and the very excellent sulphur partition ratios which were reported. I wonder how far this improved partition is a matter of the chemistry of the slag–metal equilibrium and

how far it is a question of other properties of the slag (kinetic properties) which may permit the equilibrium partition of sulphur between slag and metal to be more closely approached than usual. In normal practice, slag and metal are out of equilibrium (as calculated from laboratory experiments) by a factor of 2 or 3, so there is room for improvement in this direction.

The best way to get an answer to this question is to compare equilibrium experiments which have been done on more normal blast-furnace slags with those on high-magnesia slags. Recently, Mr. Abraham, working in my laboratory, has measured the sulphur capacity C_S* (which is proportional to the partition ratio which could be obtained in a blast-furnace under equilibrium conditions) for one of these high-magnesia slags. His result is compared with the sulphur capacity for a more normal blast-furnace slag in the following table:

SiO_2, wt-%	CaO, wt-%	MgO, wt-%	Al_2O_3, wt-%	$C_S \propto (S)/[S]$
29·7	41·6	11·9	14·8	$8{\cdot}4 \times 10^{-4}$
31·8	42·2	2·5	19·0	$3{\cdot}9 \times 10^{-4}$

The ratio of the two C_S values is 2·2 : 1 but the ratio of the partition ratios obtained in operations is about 4 : 1 (i.e. 100 : 25). Differences of temperature of the slag–metal system in the furnace might account for part of this difference but not for all of it. It therefore seems very probable that the equilibrium distribution of sulphur is more closely approached with the high-magnesia slags than with more ordinary types, possibly owing to lower viscosity.

There is a further point about the high-alumina slag to which I have just referred. Mr. Burgess and Dr. Baldwin quote its partition ratio as 100 on p. 234 of their paper, but calculation by the equation on p. 232 gives a value of 140. This seems a much larger difference than would be expected from the margin of error assigned to the formula. I would suggest that this equation is only likely to apply over a small range of composition, particularly since it is based on concentrations in wt-% of oxides which differ markedly in molecular weight. I think an equation applicable over a much wider range could be devised along the following lines:

$$\log \frac{(S)}{[S]} = \frac{K}{T}\,(wN(CaO) + xN(MgO) - yN(SiO_2) - zN(Al_2O_3))$$

In view of the way in which the work described in this paper follows from the suggestions made by Osborn, De Vries, Gee, and Kraner in 1950, I consider it important to draw attention to an error in their conclusions which might influence the design of future work on desulphurization by high-magnesia slags. According to Osborn, the sulphur partition is determined solely by the wt-% ratio $(CaO + MgO)/(SiO_2 + Al_2O_3)$ and, provided that this is constant, it is unaffected by the alumina content. Surprisingly enough this does not fit in with some of the earlier work referred to by Osborn, and so to provide an additional check on this point we recently made a few measurements of the sulphur capacities of some of the slags which Osborn and his co-workers recommend on account of their low liquidus. The results that we have obtained can be summed up as follows:

Al_2O_3, wt-%	CaO, wt-%	MgO, wt-%	SiO_2, wt-%	Liquidus, °C	$C_S \propto (S)/[S]$
15	43	12	30	1482	$8{\cdot}4 \times 10^{-4}$
20	43	12	25	1490	$1{\cdot}1 \times 10^{-3}$
25	45	10	20	1465	$1{\cdot}4 \times 10^{-3}$
30	56	5	9	1450	$5{\cdot}0 \times 10^{-3}$

For the first three slags the bases add up to 55 wt-%, yet there is a difference of almost a factor of 2 between their chemical potentialities as indicated by their C_S values. There would thus seem to be a substantial advantage in choosing not only the more basic slags but also those higher in alumina, whenever this is a practical possibility.

Another point that interested me particularly was the fact that the sulphur–manganese relationships between slag and metal were much the same as have been reported for other practices. Mr. Burgess and Dr. Baldwin give the formula

$$\frac{(S)}{[S]} = 40\,\frac{[Mn]}{(Mn)}$$

which is in good agreement with the work of Grant, Dowding, and Murphy and the studies (so far not fully reported) made by Douglas on the North-East Coast blast-furnaces. This is another indication that the one equilibrium that is fully established between slag and metal in the blast-furnace is that between manganese and sulphur. We would expect the reaction

$$[Mn] + [S] = (MnS)$$

to be a very rapid one, and certainly far more rapid than any reactions of the type

$$[S] + 2(\vdots\ Si{-}O'{-}) = (S'') + (\vdots\ Si{-}O{-}Si\ \vdots) + CO.$$

Turning to the paper describing that neat technique for measuring the liquidus of slags and studying their behaviour on melting under the microscope, I should like to ask Dr. Baldwin whether he has attempted measurements with steelmaking slags. With the steelmaking slags, much iron oxide is present, so that the slag may be opaque even when molten and iron may go into the platinum of the thermocouple and so upset it. Thanks to Dr. Baldwin's kindness in lending us his apparatus for some preliminary tests, we found, much to our regret, that his method was not suitable for studying high-manganese slags (lime + manganese oxide + silica) because of their opacity. We also made tentative studies with slags containing lead oxide; one can see through them nicely and there is no attack of the platinum by the lead. The trouble which arose in this case (and would arise with all slags containing volatile oxides) is that with such a small amount of material with a high surface/volume ratio, volatile constituents rapidly evaporate, and the composition of the slag changes markedly during the experiment.

I should like to ask two questions about the film. What was all the bubbling in the first one or two melts that we saw? Was it due to gases being caught up in the crystals and escaping on melting, or to some chemical reaction? Secondly, does difficulty of nucleation of the crystalline phases cause undercooling and so lead to differences between the temperatures recorded for melting and crystallization?

Dr. **Paul Kozakevitch** (Institut de Recherches de la Sidérurgie, France): Dr. Baldwin's interesting paper adapting the technique of Mr. Welch to blast-furnace slags is of particular interest in regard to those slags the liquidus point of which cannot be determined approximately from the diagrams of ternary or quaternary systems.

* $C_S = (\text{wt-\%S}) \times \sqrt{p_{O_2}/p_{S_2}}$.

We became convinced some years ago* that the so-called high viscosity of very basic slags was not a true viscosity of a homogeneous liquid, but was due to the presence of suspended matter (probably Ca_2SiO_4) in the slag which goes out of the furnace. Dr. Baldwin kindly determined for us the liquidus point of several basic slags with lime/silica ratios of about 1·58. He was able to confirm that these slags became heterogeneous 30° or, in some cases, even 50° C above the temperatures at which they are flowing out of the furnace as measured in the actual operation in the plant.

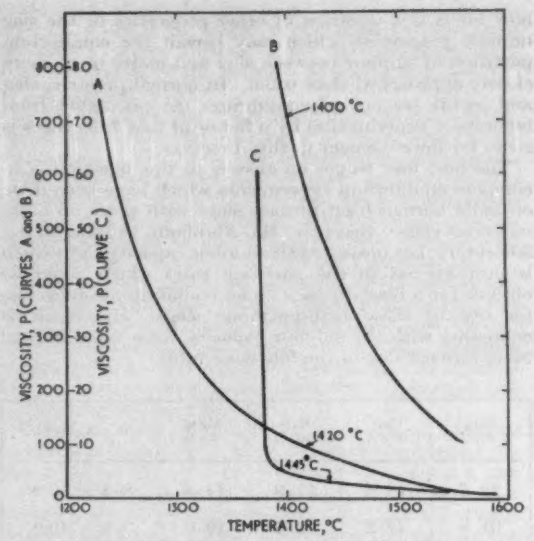
Another point which we were able to settle was the behaviour of those basic slags at very high temperatures. We found from the behaviour of our rotating viscometer that these slags, although very fluid, appeared to contain some suspended solid matter even at temperatures much higher than could reasonably be considered as their liquidus point, at 1650° C and even higher. So we supposed* that this slight heterogeneity was due to the presence of undissolved carbides. Dr. Baldwin was able to see these particles in our slags, their appearance being quite different from that of crystals formed at the liquidus point.

These two examples convinced us of the great practical utility of the technique of Mr. Welch as used by Dr. Baldwin and we shall introduce this technique in IRSID.

Mr. J. T. Shaw (British Coal Utilisation Research Association): Dr. Baldwin's practical confirmation of Osborn's assumption that blast-furnace slags are free-flowing above the liquidus, and his comment that by observing the behaviour of slags at high temperatures under the hot-stage microscope he can obtain an approximate idea of their viscosity, have aroused considerable interest in the B.C.U.R.A., where experiments are being conducted, under a contract from the Ministry of Power, on the flow properties of coal slags. Owing to the time, difficulty, and expense involved in making conventional viscosity measurements on slags, and of carrying out full-scale slag-melting trials, we have been looking for a rapid and if possible micro method which would give comparable information. Encouraged by Dr. Baldwin's success we have brought into use a hot-stage microscope similar to that of Mr. Welch and have obtained the data discussed below.

Certain experimental difficulties which do not appear with blast-furnace slags were encountered in our work. The intense self-luminosity of many coal slags at high temperatures hindered the observation of any crystals in the melt, often making it necessary to quench the bead of slag in order to observe its contents, but most of the slags were reasonably transparent when cold and vitreous. One of the slags investigated was opaque in air at any temperature but clear in a stream of pure dry nitrogen even when hot. The reason for this is not understood, and the effect of the atmospheric change upon the liquidus temperature and on the viscosity has not been determined. With one of the slags there appeared to be a change of properties on prolonged heating. This may have been due to contamination of the thermocouple wire by some constituent of the slag, to evaporation of some of the slag constituents, or to some other cause. A comparison has been made between liquidus temperatures and viscometric data for a number of coal slags and although changes of composition frequently occur while the slag is being heated in the viscometer, the comparison shows clearly that Osborn's assumption cannot be extended to coal slags. Figure *A* shows the viscosity/temperature characteristics of a blast-furnace slag (given by Baldwin) and of two coal slags, one of which is unusually fluid, the other being typical of a number of more viscous slags.

* P. KOZAKEVITCH: *Rev. Mét.*, 1954, vol. 51, pp. 569–587.



Curves A and B: coal slags. Curve C: blast-furnace slag. The vertical scale for curve C is 10 times greater than for curves A and B.

Fig. A—Viscosity/temperature curves with liquidus temperatures

When the two curves for coal slags are coupled with the observations made under the hot-stage microscope it is clear that not only did the more viscous slag remain exceedingly viscous for some 100° C above its liquidus temperature, determined under the hot-stage microscope, but also that its liquidus temperature was lower than that of the less viscous slag. This is an extreme example, but is unlikely to be invalidated by the experimental difficulties that have been mentioned. Both slags have viscosities at least ten times higher than those of the blast-furnace slags discussed by Baldwin.

The measurement of liquidus temperatures does not exhaust the scope of the technique. There are other observations, not, admittedly, of a precise nature, that may be made with the apparatus which, when combined with that of liquidus temperature, may enable an estimate to be made of the likely flow properties of a coal slag. They are:

(i) The lowest temperature at which the particles of slag powder initially on the thermocouple will coalesce to form a bead
(ii) The rate at which, at that temperature, coalescence, once started, gathers speed
(iii) The rate at which, at temperatures attainable in coal-slagging devices, crystals or bubbles move about within the bead
(iv) The proportion of the bead filled with solid matter at those temperatures
(v) The rate at which crystals grow or dissolve with given changes in temperature.

Observations of this type which we have made are not inconsistent with the measured viscosities, despite the lack of any simple law governing the relationship between viscosity and liquidus temperature; but although a skilled observer, using the hot-stage microscope, could probably at once classify certain slags as likely or unlikely to flow satisfactorily without flux, we are at the moment unable to define the scope of the technique.

Mr. J. H. Welch (Building Research Station, Department of Scientific and Industrial Research): To me the most satisfying feature of this paper dealing with the liquidus technique is the directness of approach to the question of slag behaviour at high temperatures. It is

often impossible, or experimentally too difficult, to adopt a direct approach to a scientific problem, particularly in the high-temperature field. Dr. Baldwin's paper shows what can be accomplished with a remarkably simple technique. There is no question here of inferring what may or may not be taking place in a slag at various temperatures; the observer is afforded the visual satisfaction of seeing what is going on for himself. Admittedly the volume of a slag which is being observed under the microscope is so minute that it comprises only about one part in 10^{11} of the slag present in the furnace, and one may ask whether such a small sample can be regarded as representative. I can only answer that, from the comparative results reported in this paper using a range of laboratory techniques, the results show a remarkable degree of consistency: as much as one can expect using any laboratory method to simulate a full-scale process.

I hope, therefore, that any blast-furnace operator contemplating the use of the Osborn diagrams, with or without the aid of an electronic computor to interpolate between various alumina planes, will consider the liquidus apparatus a worthwhile investment.

At the Building Research Station we are becoming more and more convinced of the widespread usefulness of this method. We have developed a modified technique for working at temperatures up to 2300° C, and we have also a high-temperature X-ray camera founded on the same principle.

If I may comment on something Professor Richardson said, we have ourselves looked at some steelmaking slags and, generally speaking, from what we have been able to observe, we think that observations are possible in some, but not necessarily all, slags. One feature which seemed to be common to all the slags which we could see through at the liquidus was that they had at least a minimal content of P_2O_5. I think it was an electric-arc slag, in which there was no P_2O_5 in the reported analysis, with which we had most difficulty. As mentioned, we have been working at temperatures of up to 2300° C, and the problem of providing sufficient background illumination there becomes even more acute than it does when one is merely looking for a final melting at a temperature of 1600°, 1700°, or 1800° C. From our experience here, I think it is possible to secure sufficiently intense illumination to reveal details of what is going on in some of the more opaque melts, even when the initial prospects appear discouraging.

The results that Dr. Baldwin has reported in his paper are of very great interest to us, and it has been a pleasure to be able to assist him in what I hope will become a major application of this technique.

Dr. **Georges Urbain** (IRSID, France): Could Dr. Baldwin give some details of the electronic computing device he used to carry out the calculations of liquidus temperatures for the quaternary systems with Osborn's data?

Dr. Baldwin's apparatus, as Dr. Kozakevitch said, is of considerable practical interest for us, and we shall try to adapt it, using appropriate thermocouples, to somewhat higher temperatures than those in which Dr. Baldwin was primarily interested. If such an extension proves to be possible, very useful data could perhaps be obtained on melts imitating the composition of certain non-metallic inclusions in steel.

Mr. **K. C. Sharp** (The Steel Company of Wales Ltd.): I have been very interested in the comments of the able scientists who have spoken. The recent work of Osborn and his co-workers has been of great assistance in indicating the range of high basic slags which can be used with perfect safety and result in the manufacture of very low-sulphur iron associated with low silicon content. In that connection one must remember that the blast-furnace operator is not presented with very easy controls.

In recognizing Osborn's work, we ought not to forget Dr. Colclough's classic paper in 1936, which drew the attention of many blast-furnace operators, including myself, to the desirability of burdening with particular attention to slag control. In that instance, attention was drawn to the method of burdening to produce the most economic slag composition. In our own case, we have set ourselves the target of producing very low-sulphur iron at reasonable blast-furnace economy. As an indication of what can be achieved by such optimum burdening policy, since 1955 over 17,000 casts have been made at the Margam blast-furnaces. Almost 14,000, or over 81%, have been within the specified target of silicons 0·4–0·7% maximum and sulphurs below 0·03%. Some 60% of the sulphurs would be below 0·02%, and 98% below 0·05%.

It is the policy of our company to produce such high-quality iron in order to meet the more rigid specification necessary in the manufacture of our rolled products. It is, of course, appreciated that such high-quality iron is not necessary in other sections of the steel industry. However, we feel that due attention to the slag composition will enable lower specifications in terms of sulphur content and certainly in silicon content to be maintained more easily. This is indicated in the paper, when the sulphur specification was altered from 0·02% to 0·04% and back again to 0·02% without difficulty.

One might ask what is the next stage? We are satisfied that we can produce low-silicon and low-sulphur iron. We may even go lower in silicon and regularly produce at or below 0·30% without difficulty. It may well be that the next stage will be to turn our efforts to burdening with even more attention to economics, and to look to external desulphurization on a large scale. The object of the exercise in our case was to produce large tonnages of low-sulphur iron and as yet I know of no method of external desulphurization which can handle very rapidly casts of up to 300 and 400 tons of iron in which the sulphur is held below 0·02%.

AUTHOR'S REPLY

Dr. **B. G. Baldwin** (in reply): Mr. Burgess and I would like to thank those who have spoken to-day and those who have discussed the paper with us beforehand for their interest. We would particularly like to thank Professor Richardson, who probably more than anybody else in this country has applied physical chemistry to the study of the blast-furnace process.

I think that in discussing the relative ease of desulphurization in the furnace by the use of basic slags, it is impossible to forget that the more basic the slag, the more fluid it is. This, I am sure, has a considerable physical effect on desulphurization and probably explains why one gets a little more desulphurization than might be expected from physical-chemical reasoning with very basic slags than with less basic slags.

The objection raised to our not using mole percentage, and the suggestion that we could have used an equation relating the function of the weight of the individual slag components are valid from the theoretical aspect. I think that blast-furnace operators are more at home with weight per cent., and for this reason we considered that the simplification resulting from using weight per cent. was justified. We will, however, examine our data in the way Professor Richardson suggests.

In the application of our results to other practices, it is important to realize that it is very dangerous to use any statistical relationship outside the range from which the data were collected.

Professor Richardson's comments on Osborn's contention that within the alumina levels studied there appeared to be no valid reason for working at any particular level are, I think, true. It is important to remember that the range of basic slags suitable for use in blast-furnaces is extremely limited in the range 20–30% alumina. For example it is not possible to run at such high basicities as we use at Margam, if the alumina level is 25%. This restriction in the slag basicity which can be used is well known to blast-furnace operators. There is an added difficulty in operating at high alumina levels, as suitable iron ores high in Al_2O_3 and low in SiO_2 are not readily available.

We agree that the relationship between manganese and sulphur is extremely important and should be of universal application.

The bubbling that was observed in the film was due in part to loss of sulphur in the slag and in part to the loss of other gases. It is very interesting to observe—Mr. Welch has had considerably more experience of this than I have—that slags, even at high temperature, contain gases. Many times I have seen slag on the thermocouple wire losing gas at a temperature just below the liquidus point. Mr. Welch has obtained some very interesting results on the influence of atmospheric humidity on liquidus measurement in the lime–magnesia–silica field and the retention of moisture at temperatures just below the melting point.

With regard to the nucleation of crystals, it was always the practice to deal with equilibrium conditions. The liquidus temperature was always approached from either side and the liquidus temperature recorded was that at which a small crystal could be maintained on the wire for a considerable period of time, such as 15 or 30 min. It is unwise to try to carry out more rapid liquidus determinations, especially on viscous slags; at least a quarter of an hour is needed to make sure that what one is observing is a true equilibrium condition.

I should like to thank Dr. Kozakevitch for his kind remarks and to say once again how indebted we in B.I.S.R.A. were to him for carrying out viscosity measurements. As a result of his assistance, we do not consider it necessary to carry out a systematic study of blast-furnace slags used in this country.

With reference to Mr. Shaw's remarks concerning the effect of change of atmosphere on slags, it must be remembered that the partial pressure of oxygen in a nitrogen atmosphere is infinitesimal compared with that in air, and substances such as Fe_2O_3 lose oxygen at high temperatures and hence the composition of the material changes. I think that a change in composition may be one of the reasons for the change in opacity and liquidus temperature. One must remember that the range of viscosities in which the coal industry is interested is much greater than those found in blast-furnace practice.

I would again thank Mr. Welch for his kind words and great assistance. With reference to the importance of sampling, I think we are helped by having a fluid material to sample from initially, but very great care is called for in sampling and specimen preparation because one is using such a tiny amount of material on the wire.

I will reply to Dr. Urbain directly and describe the method of computing. I had no hand in the development of the method which was done originally as an exercise in programming for computors. It is, of course, unnecessary to use a computor to obtain liquidus temperatures from the Osborn diagrams. Dr. Urbain referred to higher-temperature work and on this point I think he has already been answered by Mr. Welch, from whom he can get all necessary information.

The results which Mr. Sharp gave on the production of low-sulphur and low-silicon iron as routine at The Steel Company of Wales Ltd. indicates that the results obtained during our 3-week trials are in no way abnormal. With regard to his suggestion of being able to make iron with 0·3% or less silicon as a normal, I do not see any theoretical reason why this should not be possible as long as care is taken in burdening to obtain a free-flowing slag.

DISCUSSION ON A SELF-LINING BLAST-FURNACE

This discussion was based on the paper by W. A. Archibald, T. P. Brown, and L. A. Leonard, entitled **"Proposal for a Self-lining Blast-furnace,"** which appeared in the September, 1957, issue of the *Journal* (vol. 187, pp. 32–45).

Dr. **W. A. Archibald** (B.I.S.R.A.) presented the paper.

Professor **M. W. Thring** (Sheffield University): I do not think Dr. Archibald studied sufficiently in his model the distribution of gas flow. One of the most important points about his process is whether the gas goes into the little spaces between the shelves, because it is no use having a layer of material there if the gas velocity in that region is just as high as everywhere else, because then you have heat release near walls and get heat loss just the same.

I feel that Dr. Archibald is a little optimistic with the wide spacing of his shelves. One wonders how far it is going to work on the full scale. Also, these shelves are water-cooled. If you put the shelves so far apart that their surface area is equal to the surface area of the wall in between, then you might not be any better off than with a bare wall, so far as heat loss is concerned. How far does the process depend on having the two layers sufficiently far apart that their area for heat loss is considerably less than the area in between? It may be that that does not matter, and that you get such a stagnant layer right round the whole thing that it is in effect cooler within the refractory.

The centre draught producer that we were working on at B.C.U.R.A. at the beginning of the war was essentially a gadget in which you tried to get all the fine material to flow down the walls and the coarse material at the centre by the usual process of segregation with a V-stockline. You tried to reduce the gas flow up walls by having fine materials there and having a much lower gas velocity and temperature at the walls. It may be worth considering combining that principle with Dr. Archibald's principle so that the stuff that goes into the spaces shall be, as far as possible, the finer material, while the coarser material goes down the centre.

Dr. Archibald has distinguished two methods of hanging in a blast-furnace, one of which goes by freezing one way and the other by, in effect, freezing the other way. What is the exact thermal process that causes those two types of hanging? In the one case, one says that it is due to overall temperature drop, which causes a region which was liquid to become solid, and gives a tacky material frozen across. Would Dr. Archibald's cure of putting some extra heat in half-way up also cure that second phenomenon?

This question of slipping is very important. One of the things raised against the blast-furnace is the dust discharge when you get a slip which gives too much gas for the gas cleaner. How does Dr. Archibald's proposed

method of putting in heat higher up the stack compare with the method of shutting off the blast at the tuyeres every ½ h for a few seconds so that this cavity formation disappears and the burden gets a small controlled slip?

I think that the stack tuyeres are very interesting, although they are going against the whole principle of the blast-furnace, which is to keep the flow of the gases going up and the charge coming down; as soon as you start putting in heat half-way up the stack, you are going to put up the overall fuel consumption.

Finally, there is the question of who is going to try this. You can prove in the laboratory that the process is a good one, but, if nobody will try it, you are stuck. In some cases the answer is to go to the pilot-plant stage, to build a plant big enough to try out the thing and prove that it will work. I think that we must find someone with the courage to try it on a commercial blast-furnace, even if only a small one. I should also like to know how far out the coolers and the brick lining are going to stick, and whether it is going to be a firebrick or a carbon lining.

Mr. **G. H. Johnson** (Kettering Iron and Coal Co., Ltd.): The authors agree that effective work has been done to deal with conditions in the bosh and hearth, and their present proposals relate to the shaft where, admittedly, the problems are greatest. All along we have kept our eye on the development, mainly in Central and Eastern Europe, of thin-walled shafts irrigated with water. As a member of an Iron and Steel Institute party, I witnessed early experiments at Kladno and Kraluv Dvur in Czechoslovakia as long ago as 1930.

It was formerly almost standard practice to operate British furnaces with a V-stockline and with burden materials, including coke, containing a considerable proportion of fines. This led to central gas flow up the shaft, with the fines moving very slowly down the inwalls. These protected the refractory lining from severe physical wear and its life was determined mainly by the chemical attack. Simultaneously, the very slow-moving fines created favourable conditions for scaffold formation.

At the present time, the major development in blast-furnace practice is a progressive increase in the degree of burden preparation with efficient removal of fines and a corresponding increase in the percentage of sinter charged. Simultaneously, bell-to-throat radial clearances are being increased. The net effect is that the whole volume of the shaft has been brought into action, with substantial increase in output and reduction in coke consumption. The new pattern of burden preparation gives much greater action at the inwalls and the sand-blast effect of gritty particles in the ascending gas, coupled with abrasion by hard coke and sinter, has led to intense physical attack on the refractory lining.

Over a period of years the refractory makers have improved their bricks, making them more, if not completely, resistant to CO attack and also better able to resist chemical attack, but they are now faced with the problem of providing bricks which will meet the new physical demands imposed by modern furnace practice.

The Blast Furnace Refractories Joint Committee recently issued a recommendation for the properties of shaft bricks. This was a compromise between the properties which long-term research work has found desirable and the practical possibility of producing such bricks from the raw materials and equipment available. It was also necessary to make progress cautiously as bricks made specifically for abrasion resistance might fail through spalling. However, bricks complying with the recommendation are now available and some are already in service, and further linings of this type have been ordered.

The authors of this paper propose a brickless construction utilizing the refractory nature of the charge, and state that it is based on the fact that granular material can serve as a refractory if it is held in position under compression. Thus, material from the burden can be made to act as a lining provided it is a stationary coherent mass, can be held on the walls, and develops suitable properties. A practical design has yet to be evolved, and until this emerges I would hesitate to advocate a departure from the modern refractories and modern methods of shaft construction which have been developed by long-term experience and investigation.

Dr. Archibald and his collaborators are to be congratulated on their painstaking experiments but they must enlist greater support from our engineers and designers before a self-renewing shaft lining can be accepted as a lesser evil than the more conventional designs.

Mr. **H. M. Richardson** (British Ceramic Research Association): In work that we have been doing in the Blast Furnace Refractories Joint Committee, we have advocated the use of very dense bricks for the lining of a blast-furnace. I believe that this is correct but I agree with Professor Thring that we need someone to try out a self-lining blast-furnace.

There is a great deal in the paper about the formation of scaffolds and how to get rid of them but I think that a bigger difficulty will be to stop the wear of the lining, because more furnaces are blown out owing to loss of brickwork than to scaffold formation. We might find that the formation of a scaffold would be a godsend. If I had a blast-furnace lining which was granular, I would like to have a dense layer on its surface; a scaffold with a laminated iron surface would be admirable.

The blast-furnace gas reacting with the iron in the granular lining giving a carbon deposit would be another danger and would tend to disrupt the lining. It would make the granular material unstable and form a more friable material between the shelves.

It was suggested that if the idea of a self-lining blast-furnace were tried then some bricks could also be used next to the casing. I have felt for a long time that linings have been made too thick. I feel that a foot of brickwork, instead of 3 ft, in a blast-furnace may be a good thing, if the bricks are dense and adequately cooled on the outside by sprays.

A lot of theory in the paper is open to criticism. There is the concept of the formation of wide-range and sharp-freezing liquids. The idea is that a sharp-freezing liquid is one which would form a scaffold, a wide-range freezing liquid not doing so. I do not understand why. There is no mention of the viscosity of these liquids. When an alkali attacks a refractory, or the alumino-silicate in the burden, the alkali combines with the silica first and forms a viscous liquid (a wide-range freezing one) and then the alumina is dissolved, and a solid is formed; and we have a very high-melting solid formed when the alkali has reached its highest proportions of about 30%. These viscous wide-range freezing liquids when mixed with solid particles should be just as effective in producing scaffolds as sharp-freezing liquids which are surely only present in relatively small amounts.

Mr. **W. S. Debenham** and Mr. **J. B. Wagstaff** (United States Steel Corporation. Contribution read by Professor Thring.): Dr. Archibald's proposal deals with a subject that has intrigued blast-furnace men for years. Prior to 1920, many American furnaces were built with stack linings as thin as 9 in., using a water-cooled shell, following the example of several German furnaces. These proved generally unsatisfactory because, as pointed out by Archibald, external water cooling of fireclay refractories is relatively ineffective and the thin linings became thinner and failed mechanically. In more recent years, Americans have been interested in the brickless

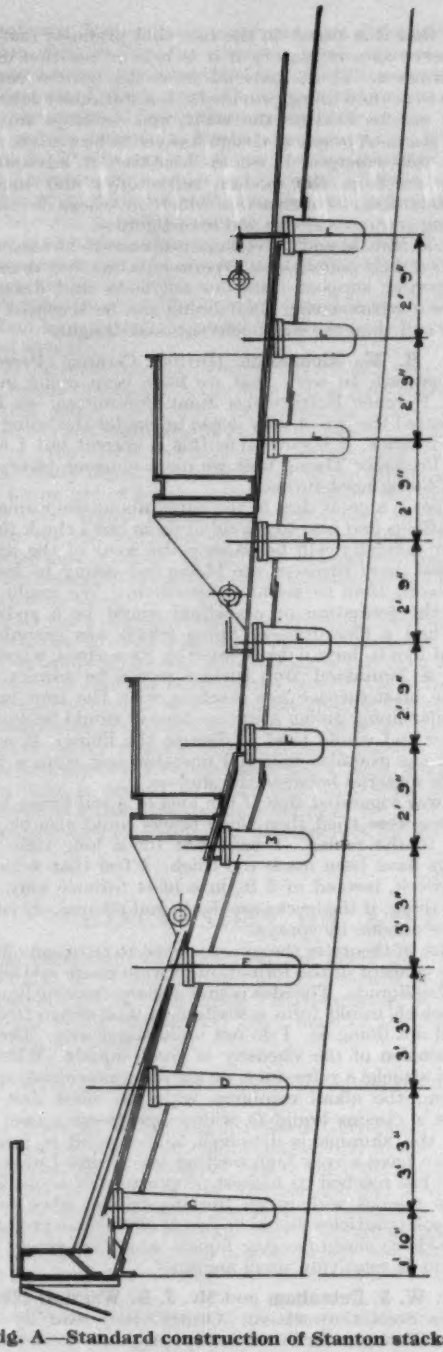


Fig. A—Standard construction of Stanton stacks

'tin top' experiments at Appleby-Frodingham, and some discussions ensued as to the feasibility of extending such construction throughout the stack with complete external water cooling from top to mantle. If, as Archibald suggests, this might result in too high heat loss despite the successful Czechoslovakian wartime experience, then his shelved construction is a logical addition to the general idea.

It would seem that detailed discussion of this paper might well be divided into two parts. First, will the solid material cling to the sides of the furnace as it does in the model? Secondly, if it does, are there any practical considerations that have been overlooked?

In regard to the first point, we are at the disadvantage that two years ago we thought we knew how the charge descended the furnace, but now we are much less certain. One feels that shelves 2 ft wide spaced 10 ft apart would not be enough to hold a layer 2 ft thick of coke and other 'stable' charge in a stationary position against the furnace walls. There is some evidence, from the use of additional coolers in a hot spot of a furnace, for thinking that the charge would move around the proposed shelves. On the other hand, Dr. Archibald's experiments seem sound, at least at first glance.

It must be realized that the laws of modelling of granular solids are not known with certainty. It is usually assumed that the ratio of model size to particle size is of no significance as long as it is above about 30. This has not been definitely proved.

Again, Dr. Archibald has worked with a homogeneous charge of granules. A blast-furnace charge is by no means homogeneous. Particle density as well as particle size vary widely from place to place at any one time. The pressures between the particles of a granular bed are not fully understood in the simple case of a homogeneous stationary bed. Very little work appears to have been done on a moving bed and none on a non-homogeneous bed. It would seem wise to be very cautious about extrapolating from these models to a working furnace.

We have had several unpleasant surprises when attempting to predict the behaviour of a non-homogeneous bed from experience of a homogeneous one. In particular, in a bed containing columns of granules of different densities, it seems that the heavier column may move somewhat faster than the lighter ones. We also feel that transport of fine material within the coarser matrix of the main charge is probably important. Little seems to be known about either of these phenomena.

In one or two cases, Dr. Archibald's conclusions are not borne out by our experience. For example, he states that "hanging cannot occur unless extensive agglomeration of the granules takes place." We have many times demonstrated hanging in model experiments without any agglomeration but by using a dusty charge, particularly if it is charged in layers.

Turning now to the practical considerations, one wonders if the authors have given adequate thought to the top of the furnace where temperatures are such that the self-lining action may not function. Is it their idea to use conventional armour or a 'tin top' construction, and would either be extended down to a point sufficiently below the stockline to allow transition to the shelf construction without disturbing the furnace lines? This is a serious question, as it is essential to maintain smooth lines below the bell for good distribution and operation.

Has full consideration been given to the volume of water required? By their formula, to maintain a 2-ft lining thickness, the average furnace would require 6 shelves completely circling the furnace at 10-ft intervals, making about 600 ft of shelving all water cooled. This is about twice the amount used with stack coolers, even when these are extended up to 35 ft above the mantle.

In our experience, the upper middle portion of the stack lining wears slightly, any difficulty being generally confined to the stockline area mentioned above and the lower stack zone. We are using stack coolers increasingly in the lower stack zone, carrying them to a height of 35 ft above the mantle. It has been observed that while these coolers do help to maintain the original furnace lines, they do not always prevent the occurrence of hot

spots resulting from poor gas distribution. The self-lining furnace might be expected to be more adversely affected under similar conditions, as the vertical spacing would be greater than with stack coolers. We experience little trouble from scaffolding, a fairly common difficulty in British furnaces; hence, it would seem that self-lining would be more adaptable to their practice than to ours. This is particularly true when it is considered that American blast-furnace brick is substantially superior to any now available in England. On an average rebuild job, the cost of refractories rarely exceeds 15% of the total cost of repairs, and considering the cost of adapting a furnace to a self-lining construction, we believe there would remain very little economic incentive for this design unless the durability of other non-refractory parts of the furnace were substantially improved.

Mr. **E. M. Summers** (The Stanton Ironworks Company Limited): The last few years have seen great progress in blast-furnace linings. We seem to have solved the problems of the hearth and bosh by the use of carbon, but few of us would claim that we have been able to build a stack which can compare in useful life with the life achieved by the carbon in the lower part of the furnace.

At Stanton we are troubled by disintegration of the lining for the first 10 ft or 12 ft above the lintel, but we do not have much trouble from scaffolds. Mr. Johnson has already pointed out that with improved furnace lines and burden preparation there is a tendency for increased activity at the walls, and as a result the lining is subjected to physical and chemical attack.

If we accept Dr. Archibald's theory of stack failure we cannot expect to improve lining life with our present methods of construction, particularly in the section immediately above the lintel. The problem can be tackled either by using a material of high conductivity, such as carbon, and building it out to the casing to produce a low inwall temperature, or by using a thin lining protected and supported by adequate cooling, or, as Dr. Archibald suggests, by putting in water-cooled shelves with no lining at all.

At Stanton we have considered this problem and, whilst we accept the merit of Dr. Archibald's suggestion, we are bothered by the obvious engineering problems associated with adapting an existing blast-furnace shell to this kind of construction. On an entirely new shell it would be comparatively easy to construct, but we should need practical proof of the effectiveness of this construction before building new furnaces to this design. For this reason I do not think it will be easy to persuade operators to try out this suggestion. At Stanton therefore we have tried to effect a compromise and the figures show the pattern of our development in lining construction.

Figure *A* shows the standard construction of Stanton stacks. You will note that we have used a conventional lining consisting of 3 ft of ceramic brickwork cooled by cigar-shaped coolers. To increase the working volume of the furnaces we have on later designs enlarged the hearth and bosh by the use of carbon and to match this we have reduced the thickness of the stack lining to 2 ft 3 in. This has had the effect of increasing the activity at the walls. On our No. 2 furnace after six months' operation we found one of the coolers in row *D* completely heeled over and the lining had disintegrated for a considerable area around the cooler. The cooler was re-aligned and fastened to the casing. We drilled holes in the casing above the cooler and pumped in some grout in an attempt to solidify the burden in that area. We put water back on the cooler and resumed normal operations. The disintegration of the lining, however, continued and in the end it was fairly obvious that for 10 ft above the lintel the lining had almost completely disappeared and

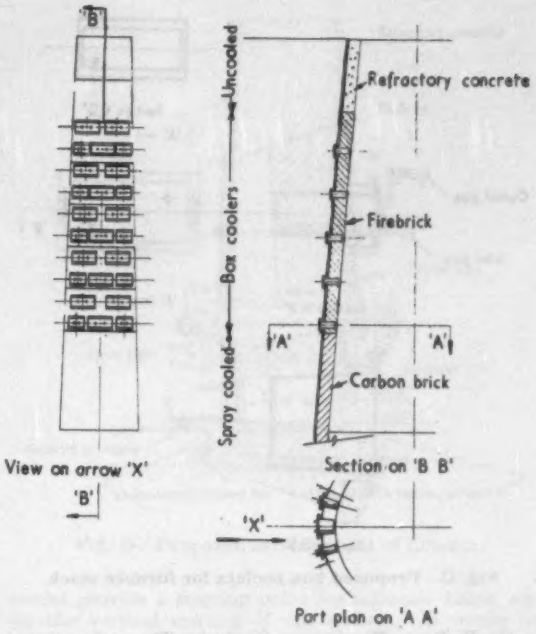


Fig. B—Latest construction

we had coolers which were fastened to the casing sticking out into the furnace.

In some respects we had unintentionally arrived at the sort of construction which Dr. Archibald has recommended except that the coolers were not continuous. This furnace has continued to operate and is doing good work although from time to time the shell gets hot and we have to resort to water sprays to keep it cool. After a time the shell cools down and the furnace appears to be quite normal. We attribute this to the fact that from time to time the burden which has built up between and around the coolers breaks away and we get a period when the shell is very hot. The burden then appears to build up again and the shell cools off.

Figure *B* illustrates our ideas of future construction. You will note that we have abandoned the expansion gap between the casing and the stack lining and in the bottom 10 ft of the stack we are proposing to use carbon to produce the low inwall temperature which we consider is desirable in this area. The carbon will be cooled by external sprays. Above the carbon we are proposing to put in box-shaped coolers which are designed to fit into and form a mechanical part of the stack lining, and, as you will see, they are so spaced as to form an almost continuous shelf.

Figure *C* shows detail of the proposed coolers and how they fit into the brickwork of the stack. Between the coolers we are proposing to use the high-grade ceramic bricks mentioned by Mr. Johnson and Mr. Richardson.

Figure *D* illustrates the complete design, and it will be seen that, whilst we have not completely accepted Dr. Archibald's ideas, the top half of the stack bears some resemblance to his suggested construction, except that the cooling shelves are not continuous and we are proposing to put brickwork in between. In the lower part of the stack we feel that carbon will give the better performance, but, if this proves not to be the case, we may have to re-design that part of the furnace in a similar way to the upper part of the stack.

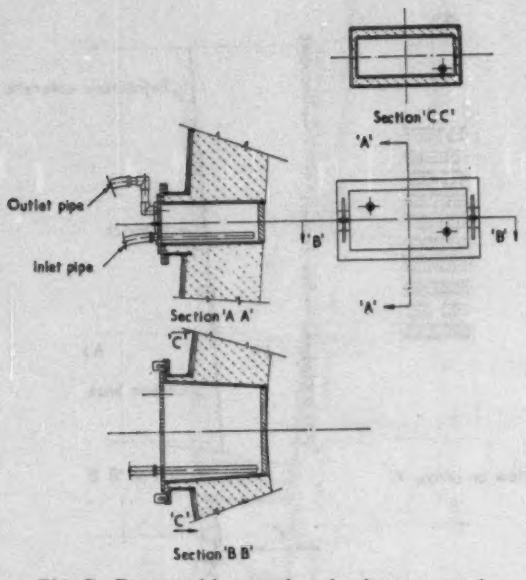


Fig. C—Proposed box coolers for furnace stack

Mr. **K. Bose** (The Coppee Co. Ltd.): The author states that the idea of shelves is to make the lining thinner and consequently to increase the capacity of the furnace. I take it that he means increase the volume of the furnace. To some people the capacity of a blast-furnace means the tonnage that one gets out of it per day, which, broadly speaking, depends on the volume of the furnace, the rate of driving, the nature of the iron, the iron content, and the coking rate. So volume is one factor among several.

The question I should like to put is whether the volume increase gives maximum production. We have seen that the modern trend is towards bigger and bigger furnaces. We have 28-ft to 30-ft diameter blast-furnaces, with volumes of about 40,000–50,000 ft³. I should like to know whether the increase in volume gives a bigger yield.

The second question is what should be the optimum volume size of a blast-furnace that will give maximum iron production?

CORRESPONDENCE

Professor **S. Cernoch** (Košice Technical University, Czechoslovakia) wrote: I should like first of all to mention that the gas and burden in the blast-furnace form a three-dimensional temperature field, the surfaces of constant temperature being more or less symmetrical to the furnace axis and having a characteristic **W**-shape extending to considerable heights. This field controls the physical and chemical processes occurring in the space above the tuyeres. The temperature distribution and gas analysis are functions of gas-flow distribution, the greater the temperature variations of gas in horizontal sections of the space above the tuyeres, the greater the number of processes occurring in those levels. The growth of these irregularities in physical and chemical properties at various levels impairs the regularity of gas flow. The physical and chemical processes of the burden are then dispersed at different levels. The utilization of thermal and chemical energy of the gas decreases and decrease of output follows. These irregularities of temperature distribution in the burden represent a factor limiting the output of the furnace, this factor itself being a result of increasing the volume of the blast. The evolution of the blast-furnace and its output is connected with the gas-velocity uniformity. For this purpose ten or twenty years ago there was a tendency to diminish bosh height and increase its angle but nowadays, when the size of the hearth diameter is growing, the bosh angle is diminishing, and the velocity of blast in the tuyeres is increasing. Improved burden homogenization and its distribution in the stack, new charging devices, and automatic blast also have this effect. Scaffolds, arches, and hanging always unfavourably influence the gas velocity and temperature distribution and therefore decrease the furnace output.

Dr. Archibald and his co-workers give a convincing explanation of the main factors influencing scaffold and arch formation and hanging. I would like to add a few words about the influence on these phenomena of stack construction.

Contemporary thick-walled stacks use intermittently placed horizontal cooling boxes and, after some months of blowing-in, these boxes are exposed and they protrude into the furnace like crocodile teeth. The burden descends heavily and unevenly between these boxes, with high internal friction, and crushes the material descending outside the cooling boxes. What an absurd way of transporting granular material! As a result much dust is formed creating favourable conditions for scaffold formation and for the development of gas-flow irregularities and channelling. The modern blast-furnace works on the periphery so that gas velocities near the stack wall are essentially higher than average. This high velocity is limited to a narrow space and is very sensitive to resistance changes caused by material flow near the wall in the manner described above. These changes of gas flow bring about temperature fluctuations in this space—an essential condition for scaffold formation. Another possibility is that the material deposited on the horizontal surface of the cooling boxes is chilled increasingly by the cooling water. The hanging of larger arches, and indeed any hanging at all, is supported entirely by the bare cooling plates. This very rarely occurs in furnaces with smooth walls and is more likely in thin-walled furnaces. With increasing output, the smooth wall of stack and bosh appears to be an important condition for correct materials-flow and temperature stabilization in the space above the tuyeres.

The wear of the brickwork produces severe changes in the furnace profile especially in the upper stack. This demonstrates a further disadvantage of the contemporary thick-walled construction. These changes of profile favour peripheral gas-flow and the tendency to temperature instability. As is known, the furnace creates its own profile and it must be said that this process always impairs the gas-flow distribution and the blast-furnace process. For this reason the use of the brickwork in stack construction mentioned by Oreshkin[4] cannot be defended. Stack shells having only cooling plates would be better in many respects. Simply stated, for high-output furnaces the stack and the bosh must not be permitted to form their own profiles. This condition is to a great extent fulfilled in thin-walled construction.

Many experienced blast-furnace specialists of leading iron-producing countries, whom I have met abroad, are becoming more opposed to this type of construction, declaring that the heat losses of the stack walls are greater than with thick-walled furnaces.

It is necessary to show that the stack-wall heat loss in cooling water in thick-walled construction plays a subordinate role in the thermal balance, being lower, or reaching, at the worst, a maximum of about 2%.[1, 2] As is

known, there are other larger items of coke consumption in this balance. Most of these items are larger in the thick-walled construction. So that the higher coke-consumption is due to troubles and irregularities of this type in the furnace working, the consequence of hot-gas turbulence caused by scaffolds, arches, and hanging, the furnace's own profile formation, and the materials down-flow as described previously. A small coke-consumption and a large output does not depend on wall heat-losses, but mainly on the smooth working of the furnace. This furnace with a smooth interior is contemporarily represented by the thin-walled type. A further surprising fact is that a comparison of water quantity and temperature does not show any difference in the heat losses of the two types. This is a fact which we can only try to explain. For this purpose let us compare the surfaces of bare cooling boxes with the surface of a water-cooled shell of thin-walled construction. Let us further consider the heat-transfer coefficient due to convection in the case of the free-running water on the shell and in the case of the much faster flow inside the cooling boxes. When the differing coke consumptions arising from thin- and thick-walled designs,[3] from the old bosh profile, from differing numbers of tuyeres are compared, the differences may be due to the number of tuyeres and not to wall heat losses. It is evident that the thin-walled blast-furnace No. 5 at Feldklingen has insufficient tuyeres (bosh dia. 5800 mm, 10 tuyeres). The main problems of the present large-diameter thin-walled furnaces are the thermal and mechanical stresses in the upper part of the stack shell. These stresses were eliminated by a layer of burden material especially with the first smaller riveted shells.[6, 7] As mentioned in Dr. Archibald's paper (Fig. 19), for the present large welded furnace shell, circular water-cooled ribs were proposed [6, 7] and installed during the past year. In one furnace bosh-cooling plates without any other brickwork were installed in the stack. In Poland[9] some thin-walled constructions with inclined steel sheet ribs are also working. In the upper part of the stack a larger number of these ribs are placed and welded during the laying of the brickwork. Some German blast-furnace specialists have had experiences similar to ours.[5]

From the standpoint of further blast-furnace output, reinforcing the thick-walled construction of the stack with horizontal cooling boxes is the most unsatisfactory part of the present blast-furnace design. Thirty years' experience with thin-walled construction suggests a new approach.

Stack tuyeres were also installed in our country.[7] In the last few years these installations were given up owing to the complicated, and not too efficient operation. New techniques of distributing the material in the stack and new charging devices have helped to solve the problem of reducing scaffolding.

This paper by Dr. Archibald and his co-workers is a valuable contribution to furnace-stack design, and I congratulate him on his experimental technique. The self-lining principle has been successfully used for a long time on shaft-furnaces in the non-ferrous industry. It is mainly applied in the bosh zone of this type of furnace. Deposition on the stack, since the shaft-furnace walls are at less than 90°, is difficult to carry out.

AUTHOR'S REPLY

Dr. **Archibald:** I agree with Professor Thring that a satisfactory melting model for the study of ironmaking in the blast-furnace would be as desirable as it would be complicated. I also agree that even our simpler study of flow introduces uncertainties in similarity conditions. None the less, I feel that the results obtained with our model provide a starting point for full-scale trials, e.g. on the vertical spacing of the shelves. It would be possible to devise a technique to simulate hanging and arch-residue scaffolds at low temperature, comparing s.f. and w.r.f. liquids. However, as the results are predictable from simple phase-diagram considerations described in the paper, such experiments were not considered necessary.

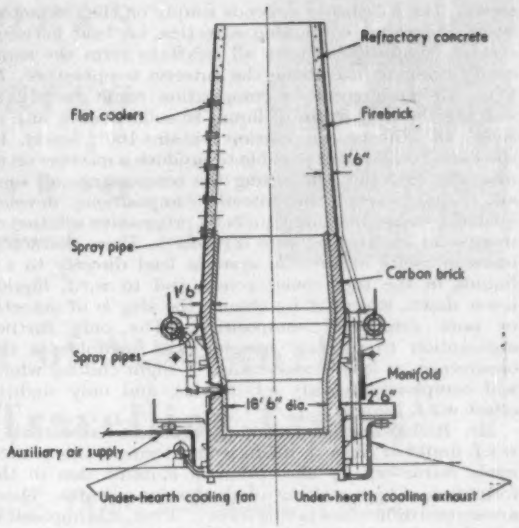


Fig. D—Proposed arrangement of furnace

Professor Thring is obviously correct in observing that the shelves increase the internal area of cooled steel, and that this would increase heat losses unless much of this area is protected by good thermal insulation. The shelves scheme depends on the trapped burden serving in this way, and this is supported by our observations. Re-consideration of the two types of scaffold leads me to conclude that our Fig. 9*b* is greatly exaggerated, i.e. a laminated scaffold growing at a substantially steady temperature should be very thin. The arch-residue scaffold, on the other hand, is likely to be quite extensive because it is not possible to envisage a very thin restricted volume being subjected to chilling. These characteristics agree with those of many scaffolds described in the literature.

Since modern practice aims at eliminating fines, these cannot be used by special charging methods to protect the walls. Initial installation of suitable monolithic materials (containing fines), or of bricks, might be useful. Trials would have to be made to assess the relative merits of shaking and stack tuyere operation in preventing hanging and scaffold formation, although the latter should increase the heat losses only very slightly.

Mr. Johnson points out the great effort that has been directed towards improving the refractory to compensate for the effect of harder driving. This is surely a losing battle and extra defences in the form of shelves are worth considering to assist, if not to replace, the improved refractories.

I agree with Mr. Richardson that, in general, the problem today is wear rather than scaffolds. I also favour thinner linings though I imagine they will be adopted mainly to increase the capacity of the furnace.

Mr. Richardson and I agree that hanging and scaffolds are caused by setting of liquid films in the burden. We disagree, however, on the mechanism causing the liquid

to set. The s.f. theory depends simply on the characteristics of systems containing eutectics, i.e. that between certain composition limits all mixtures form the same eutectic liquid just above the eutectic temperature, T_1 (Fig. 6). Differences in composition result merely in varying the proportion of liquid to solid phases, and of course the eutectic composition contains 100% liquid. In the blast-furnace it is possible to produce a mixture on or near the eutectic. On raising the temperature all such s.f. liquids, except the eutectic compositions, develop into wide-range freezing liquids by progressive solution of more solid until the liquidus is reached. These characteristics of melts in eutectic systems lead directly to s.f. liquids in the top, cooler zones, and to w.r.f. liquids lower down, except if by chance the slag is of eutectic or pure compound composition. The only further assumption to produce hanging and scaffolds is the occurrence, at least occasionally, of slight chilling which will completely solidify s.f. liquids, and only slightly affect w.r.f. liquids.

Mr. Richardson's counter theory postulates that a w.r.f. liquid of silica + alkali is first formed; this is then made refractory by absorption of alumina due to the formation of high-melting alkali alumina silicates. There are several difficulties in this theory. First, it is impossible to allocate such an order of combination or reaction. Secondly, his w.r.f. liquid would have been s.f. when it first appeared further up the furnace. Thirdly, the chief implication of an ' eutectic ' system is that a mixture of high-melting components produces some proportion of low-melting eutectic. If he consults the alkali–alumina–silica diagrams he will observe several ternary eutectics melting between 900° C and 700° C and containing about 30% of alkali. For a given temperature the composition of the mixture determines what sort of liquid exists. Additions of alkali or alumina, as slag dust or mist, etc., will change the character of the liquid depending on nature and amount, but no generalization about it making the mixture more or less refractory can be made. The viscosity of the liquid is involved in hanging and scaffold formation, but is of secondary importance compared with solidification. The minor role of viscosity is briefly referred to in a footnote on p. 37.

The effect of disintegration reactions is dealt with in the text (p. 40) under " Chemical Properties of Static Material " where it is shown that no loss due to this cause should occur in a shelved design.

Messrs. Debenham and Wagstaff's recollection of early American thin-walled furnaces again underlines the difficulty of extracting enough heat to cool the hot face significantly until or unless the refractory layer is extremely thin. It would be of interest to hear exactly how these early furnaces failed mechanically. Numerous references to long service after the top brickwork has disappeared, including those to the Appleby Frodingham ' tin top,' seem to offer hope for a bare stack. I agree that whether or not shelves are required depends on the heat loss. In Czechoslovakia, Professor Černoch appears to have found this to be low. Messrs. Debenham and Wagstaff's experience of model work is interesting particularly on the occurrence of hanging. In their model, agglomeration causes hanging presumably as a result of internal frictional and locking forces between the fine particles. I think it is reasonable to suggest that, if strong ceramic bonds are formed in the burden, they should dominate its mechanical behaviour. Only slight chilling has to be postulated to produce ceramic bonds in the upper levels.

I agree that the top of the furnace requires special treatment. I would suggest the use of either a bare ' tin top ' or a shelved construction fitted with special abrasion and disintegration-resistant bricks which need not be highly refractory, e.g. fusion-cast quartz or blast-furnace slag. The quantity of water required in a shelved construction may be higher than usual but it might well be justified.

As regards the economics of a shelved shell, the aim is not to save the 15% of rebuild cost spent on refractories but to increase the reliability and availability of the furnace. Conclusions about the occurrence of hot spots in a shelved furnace arrived at from the behaviour of ordinary linings containing cooling elements are dangerous unless full allowance is made for the critical differences in principle of construction. We find that when this is done the indications are most hopeful.

Mr. Summers's experience that, when carbon bricks are used in the hearth and bosh, the stack becomes the weakest link is likely to become general. His observation of the long life of the shell after much of the stack brickwork has been lost substantiates the feasibility of the self-lining furnace. I welcome his faith in this proposition and the steps he has taken in its practical development.

I agree with Mr. Bose's distinction between capacity and volume. I would merely say that it is the increase of capacity that is vital and that increase in volume up to present maximum sizes contributes to output. Thus the optimum volume has presumably not been attained or, if it has, it is limited by mechanical factors. Professor Černoch's contribution is particularly welcome as it is based on full-scale practical trials which have led to a very similar shelved design being installed this year. I agree with much of what he says but have reservations on the importance of projecting ledges being the cause of hanging; however, this is not easy to prove definitely either way, by model work or by full-scale observations. I would only reiterate that as long as the furnace granules are not agglomerated they behave rather like a liquid and will flow readily down a wide tube even if it is roughened (by ledges). I would expect the most efficient profile to be that of a parallel tube. Basically, I agree with Professor Černoch in advocating, in order of preference,

(i) Bare cooled shell (if neither excessive heat losses nor other disabilities are encountered)
(ii) Thin lining ringed with shelves (if (i) is unsuccessful)
(iii) Thick lining ringed with shelves (where preferred).

I would deprecate the use of water coolers except as mechanical baffles since their cooling effect extends over such small volumes of refractory.

I think he makes a very important point when he says that for efficient fuel consumption, smooth working is far more important than heat losses from the walls. I was disappointed to hear of his unsatisfactory experiences of stack tuyeres. We would restrict their use to self-lining structures and only if the problems of hanging and scaffolds were not more simply solved by other means such as charge preparation or shaking.

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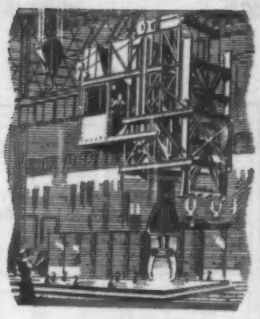

Structural Design of Steelworks Electric Overhead Travelling Cranes

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SYNOPSIS

This paper discusses the structural design of steelworks E.O.T. cranes as involving three main points: the correct assessment of the loadings to which the structure is subjected, the use of a reasonably accurate and comprehensive method of stress analysis, and the employment of appropriate permissible stresses.

In the assessment of loadings, data are presented from tests carried out on ten steelworks E.O.T. cranes using electrical resistance strain gauges. Suggestions are put forward regarding the allowances to be made for snatch hoisting, long-travel motion, ingot-stripping, pit-scraping, and forging operations. For stress analysis, the general structural problem of box-type structures is considered and approximate formulae are developed which are shown to be satisfactory in comparison with measured stresses. Lastly, the difficulties associated with determining appropriate permissible stresses for fabricated structures under varying loads are referred to and the approach of current specifications given.

It is concluded that to achieve lighter structures for steelworks E.O.T. cranes, whilst at the same time maintaining their safety, close attention to all aspects of design is required on the lines put forward in the paper.

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IN THE OPERATION of steelworks' plant a very important part is played by E.O.T. cranes in all stages of production. To avoid interruptions to the production process, and also from the point of view of safety, a high degree of reliability is required from these machines. In the design a balance is needed between robustness and lightness, bearing in mind that while a crane of substantial construction may be very reliable, a considerable penalty has to be paid in terms of the massive girders, columns, and foundations required for its support. As well as the actual crane structure, the mechanical and electrical equipment, access walkways, etc., may also, if not carefully considered, lead to undue weight being carried. It is, in fact, well known that for various reasons present-day replacements are much heavier than their older counterparts.

Within the structural field several aspects of the requirements of correct design may be distinguished, namely,

(i) Detailed knowledge of loading
(ii) Accurate method of stress analysis
(iii) Appropriate permissible stresses.

To cover these aspects, a series of stress recordings from steelworks' production cranes carrying strain gauges fixed to the crane bridge structure has been made by B.I.S.R.A., and, parallel with this experimental investigation, an attenpt has been made to evolve a more comprehensive design method, the main point of which is to take into account the live loading of the auxiliary (or outrigger) girder without becoming too elaborate for general design office use. A solution of the difficult problem of permissible stresses has been attempted here and in the B.I.S.R.A. Specification for Heavy Duty E.O.T. Cranes in Iron and Steel Works (1955).

LOADING

In steelworks, cranes are subjected to a great variety of dynamic loadings according to their particular duty. Cranes differing vastly in size are in use, fitted with handling devices appropriate to the material being moved. There are, for example, hoist rope cranes equipped with grabs, magnets, or turning-over gear and stiff-masted cranes designed for stripping and lifting ingots or for charging furnaces with scrap, etc. To obtain further information

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The authors were both on the staff of the Division when this work was carried out. Mr. Tyler has since become a Lecturer in the Aeronautical and Mechanical Design Department of Hatfield Technical College.

Table I
DISTRIBUTION OF WEIGHTS IN CRANES TESTED

	1	2	3	4	5	6	7	8	9	10
	Crane	Span, ft.	Lifted Load	Weight, tons			Ratios			
				Crab	Girders	All-up Weight (inc. load)	Load / Crane weight (exc. load)	Crab / Load	Girders / All-up weight	Girders / Crab & Load
1	Forging	70·0	250	102	81*	500	1·00	0·41	0·16	0·23
2	Forging	53·5	100	43	34·6*	204	0·96	0·43	0·17	0·24
3	Ladle	78	250	152	132*	641‡	0·64	0·61	0·21	0·33
4	Ladle	65	100	50**	35**	...	...	0·50	...	0·23
5	Ingot stripping	67·8	8	47	20†	...	...	5·90	...	0·36
6	Ingot charger	65	7	41	25	92	0·08	5·85	0·27	0·52
7	Box charger	63·6	5	30·5	25*	71	0·08	6·10	0·35	0·71
8	Grabbing	117·5	16	34·5	29†	96	0·20	2·16	0·30	0·57
9	Plate handling	70	20	15·4	37·8*	82	0·32	0·77	0·46	1·07
10	Ingot handling	56·2	5	3	9*	18	0·38	0·60	0·50	1·12

* Excluding long-travel gear
† Excluding long travel gear and platforms
‡ Excluding auxiliary hoists of 50 and 15 tons
** Estimated values

about the dynamic loading of all these types of crane, an experimental investigation using electrical resistance strain gauges has been carried out and some of the results are given below. As a preliminary, the dead and live loadings and stresses have been considered generally.

Magnitudes and Proportions of Dead and Live Loadings and Stresses

At a recent conference on steelworks cranes an example was quoted[1] of a recently built 10-ton crane of 112 ft span, with over 2000 ft² of platform, walkways, etc. Out of a total crane weight of 76 tons, the accesses and the accompanying increase in girder sections accounted for 19 tons, or 25%. While this is no doubt an extreme case, it is of interest to consider the magnitudes and relative proportions of the principal loadings, and also the resulting stresses, occurring in the ten crane structures which were the subjects of the series of tests.

Table I shows the all-up weights of the cranes (column 6), and the principal component weights—lifted load (column 3), crab (column 4), and girders (column 5). The total weights, including load, range from 18 to 641 tons, and most of the main types of steelworks crane are included. A steelworks ladle crane similar to one of those tested is illustrated in Fig. 1.

In columns 7–10 of Table I, four weight ratios have been given—load/unloaded crane, crab/load, girders/all-up weight, girders/crab and load. Brief comments on these ratios may be made:

(*a*) *Load/Unloaded Crane*
An obvious feature is that this ratio is very much higher for the heavier cranes (1–3) than for the lighter cranes (8–10). The values for the stiff-masted cranes (6 and 7) are exceptionally low (0·08), owing to the particular construction necessitated by the crane duty, and are not comparable with the others.

(*b*) *Crab/Load*
The trend shown is that the relatively lighter crabs appear in conjunction with the heavier loads. The values shown for the three stiff-masted cranes (5–7) are remarkably constant at about 6 to 1.

(*c*) *Girders/All-up Weight*
These ratios give some indication of the reduction in all-up weight possible by economizing in the crane girder structure, assuming the remainder of the crane to be unaltered. The greatest scope lies in the hoist-rope cranes of low load-carrying capacity (8, 9, and 10), where the girder/all-up weight ratio reaches 0·3–0·5.

(*d*) *Girders/Crab and Load*
The range of values of this ratio is fairly wide (0·23–1·12), but perhaps not unduly so in view of the very wide range of loadings.

The effects of the loadings in terms of the dead and live load stresses in the bottom main members of the crane girders are shown in Table II. The stresses due to the self-weight of the girders (column 3) are calculated, but the other values for lifted load (column 4), crab weight (column 5), and dynamic loading (column 7) are based on measured stresses

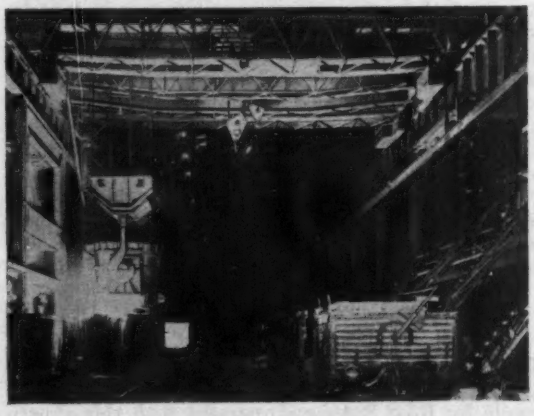

Fig. 1—280-ton ladle crane

Table II

MAGNITUDES AND PROPORTIONS OF DEAD AND LIVE LOAD STRESSES IN BOTTOM MAIN-GIRDER MEMBERS

	1	2	3	4	5	6	7	8	9	10	11
	Crane	Safe Working Load, tons	Stresses, tons/in²					Percentages of Total Static Stress			
			Dead Load	Lifted Load	Crab Weight	Total Static (3), (4), and (5)	Additional Dynamic Loading	Dead Load	Lifted Load	Crab Weight	Additional Dynamic Loading
1	Forging	250	0·6	2·4	1·0	4·0	2·8	15	60	25	70
2	Forging	100	0·5	1·9	0·8	3·2	1·5	16	59	25	46
3	Ladle	250	0·8	1·6	1·0	3·4	0·2	24	47	29	5
4	Ladle	100	0·4	1·7	0·9	3·0	2·2	13	57	30	73
5	Ingot stripping	8	1·2	0·5	2·8	4·5	1·0	27	11	62	22
6	Ingot charger	7	0·8	0·5	2·4	3·7	0·6*	22	13	65	16
7	Box charger	5	1·3	1·1†	2·1	4·5	0·7	29	24	47	15
8	Grabbing	16	1·1	0·9	2·0	4·0	Not measured	28	23	50	...
9	Plate handling	20	1·0	0·9	0·7	2·6	0·2	41	33	26	7
10	Ingot handling	5	0·8	1·1	0·7	2·6	0·5	32	42	26	18

* During long-travel motion. Soaking pits towards end of span.
† Includes effect of arm perpendicular to bridge.

recorded during the tests. With the exception of cranes 9 and 10, a number of gauges were placed round the bottom main-girder member and the stresses in Table II are, in the case of lattice-girder cranes (1, 4, 5, 8), the primary stresses for the member or, for the plate-girder cranes (2, 3, 6, 7), the mean of the gauge readings.

The general level of the total static stresses given in column 6 is not high, a maximum value of about 4½ tons/in² being reached. Including the dynamic loading, the stresses rise, in one case only, to 6·8 tons/in² but are otherwise not higher than 5½ tons/in² and so are within the commonly used 6 tons/in² allowable stress stipulated by B.S. 466: 1947 (E.O.T. Cranes for general use in factories, workshops and warehouses).

The lowest values of about 2½ tons/in² total static stress are shown for the 20-ton plate-handling crane and the 5-ton ingot-handling crane (9 and 10). These are the cranes having (Table I, column 10) the highest weight of girders relative to the combined load carried, and it would appear therefore that possibly these types of crane are the ones that would benefit most from closer design of the girder structure. In general the experience of these tests seems to confirm that of Lightfoot,[2] namely, " that in small cranes the design may be controlled by the sections available and by methods of joint construction " rather than by the limitations imposed by the maximum allowable stresses in the specifications.

From the weights given in Table I it is apparent that, while the ratio of load carried to crane weight may occasionally rise for the larger present-day cranes to the fairly reasonable value of unity, the general picture is not so satisfactory, and the question of the greater weights of modern cranes compared with those of 30–40 years ago has been the subject of recent discussions. One crane manufacturer has suggested[3] that platforms should be cut down to one bay at each corner and a narrow walkway across each bridge, and also that further weight might be saved by using light alloy for platforms, handrails, cage, contactor house, and stairways. Other suggestions have concentrated on the possibilities of high-tensile steel for the structural members and the reduction of dead loading by the elimination of the long-travel motor shaft and long-travel motor (which is necessarily placed centrally in the worst position with regard to stresses). Tubular construction has also been put forward as a means of minimizing the girder self-weight. Reduction in crane weight may only be achieved at some extra cost, due to closer design or the use of tubes or materials other than mild steel, but this might be justified economically by the resulting saving in the material required for the supporting girders and stanchions and in electrical power.

Snatch Hoisting

There are many cranes in the steel industry, such as grabbing, plate-handling, or scrap-handling cranes, on which vertical impact loading occurs principally owing to the rapid hoisting, or lowering, of the load; cranes 8, 9, and 10 of Tables I and II belong to this group. Ladle cranes may also be generally considered with these, although the low hoisting speeds and the care necessary when handling the full ladle generally prevent the occurrence of any severe impact. The 100-ton ladle crane tested (crane 4, Table I) was of an old continental design with stiff guides for the cross-beam, and the relatively high dynamic stresses shown in Table II occurred during long-travel motion and not during hoisting operations.

General-service cranes as used in all industries are also cranes in which the impact effects may be taken to be largely due to hoisting operations, and hence this particular aspect of dynamic loading has received considerable attention in practical testing and theoretical analysis.[2, 4] Table II shows that in the present series of tests the two cranes of this type (9 and 10) for which dynamic stresses were measured showed impact effects due to snatch of about 20% and 40% respectively. These values depend on the particular conditions of the tests, especially the hoisting velocity at snatch. Lightfoot and Clarkson[5] reported impact effects of 21–46% for three cranes lifting approximately the rated working load (5–20 tons) with the

Table III

STRESSES DUE TO LONG-TRAVEL MOTION

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
	Crane	Safe Working Load, tons	Dynamic Stresses, tons/in²				Static Stresses,* tons/in²				Ratios Dynamic/Static			
			Main Girder		Auxiliary Girder		Main Girder		Auxiliary Girder		Main Girder		Auxiliary Girder	
			Top Boom	Bottom Boom	Top Boom	Bottom Boom	Top Boom	Bottom Boom	Top Boom	Bottom Boom	Top Boom	Bottom Boom	Top Boom	Bottom Boom
3	Ladle	250	0·1	0·2	0·5	0·5	1·9	2·6	1·2	1·6	0·05	0·08	0·42	0·31
4	Ladle	100	2·2	2·2	...	...	2·0	2·6	...	...	1·10	0·85	...	...
5	Ingot stripping	8	0·5	1·0	1·5	1·1	2·4	3·3	2·7	1·7	0·21	0·30	0·56	0·65
6	Ingot charger	7	...	0·6	2·2	1·2	...	2·9	3·0	3·4	...	0·21	0·73	0·35
7	Box charger	5	0·4	0·7	0·7	0·3	3·0	3·2	1·9	1·5	0·13	0·22	0·37	0·20
9	Plate handling	20	0·1	...	0·1	...	0·9	1·6	1·1	...	0·11	...	0·09	...
10	Ingot handling	5	0·3	0·5	0·3	0·4	0·4	1·8	0·2	0·9	0·75	0·28	1·50	0·44

* The static stresses are those due to the weight of both crab and load.

crab centrally placed or nearly so. The hoisting speeds were 3–6 in./s (15–30 ft/min). As a result of the tests and a comprehensive analysis, they proposed that the simple formula

$$I = CV$$

where I = impact effect (excess above unity)
V = rated hoisting speed, in./s
C = constant

deserved considerations for design purposes, values of C being suggested for different classes of cranes as given in B.S. 2573 : 1955 (0·1 for Class II and 0·16 for Class IV for a 10-ft fall of rope).

These investigators also showed that, of various dimensionally correct formulæ, the one giving closest agreement with all test results was of the form

$$I = 0{\cdot}88\,\frac{V}{m_2 g\sqrt{\left(m_1 k_2\right)}}$$

where m_1 = equivalent mass of girder and crab, tons
$m_2 = \frac{1}{2} \times$ lifted load, tons
$k_2 = \frac{1}{2} \times$ tackle stiffness, tons-weight/in.
$g = 384$ in./s²

No term for the crane girder stiffness appears in this expression, indicating that it has only a minor influence on the impact factor and that much greater effects are produced by variations in the tackle stiffness. This result has been confirmed in parallel theoretical investigations by the present authors.

Fig. 2—5-ton overhead box charger

The formula also shows that an increase in the girder and crab weights (m_1) will lead to an increase in the impact effect.

Generalization of the snatch impact effect is, in fact, difficult in view of the number of variables involved, but the results of all tests seem to indicate that the value of 50% given in the B.I.S.R.A. Specification for steelworks E.O.T. cranes is reasonable, although it may be exceeded under some extreme circumstances.

Long-travel Motion

The crane loadings due to long-travel motion may be considered to result from the acceleration of the crane and load and the roughness of the track. Of these, the acceleration (or deceleration) broadly gives rise to horizontal forces and the track condition to vertical forces: In practice the effects are generally combined and it is almost impossible to separate them by a study of the stress records. In Table III the results are shown for the seven cranes on which long-travel tests were carried out and no attempt has been made to identify the individual effects. The stresses given in columns 3–6 of the Table are the maximum additional dynamic stresses observed in the top and bottom booms of the main and auxiliary girders, the strain gauges being situated as close to mid-span as convenient. In the tests the load was carried at mid-span and the cranes travelled several times in both directions. Static stresses are given in columns 7–10 of Table III, these being the stresses due to the combined weight of crab and lifted load under static conditions. Columns 11–14 then give the ratios of additional dynamic to static stresses.

The cranes listed may be divided into two groups, one consisting of cranes 3, 9, and 10 (ladle, plate, and ingot handling), in which the load is carried by hoist ropes, and the other consisting of cranes, 5, 6, and 7 (ingot-stripping, ingot-charger, and box-charger), in which the load is carried at the end of a stiff mast. The 5-ton box charger, shown in Fig. 2, is illustrative of the stiff-masted type of crane. The old ladle crane (4) is effectively in the second group by reason of the stiff guides for the cross-beam, although the load is actually carried by ropes.

The hoist-rope cranes of the first group show only low dynamic stresses, not exceeding $\frac{1}{2}$ ton/in² in both main and auxiliary girders, whilst the stiff-masted cranes show much higher dynamic stresses of up to 2 tons/in². As the speed and acceleration of the stiff-masted cranes were not markedly different from those of the other group, some other explanation of the difference in dynamic stressing has to be found. Some allowance has to be made for the generally higher level of static stress in the stiff-masted cranes as compared with two (9, 10) of the hoist-rope cranes, but in the case of the third hoist-rope crane (3) the static stress level is comparable with that of the stiff-masted cranes. It is apparent from columns 5 and 6 of Table III that for the stiff-masted cranes the top auxiliary members were more highly stressed than the bottom auxiliary members, and, as will be shown, this indicates that in estimating the resultant long-travel loadings account must be taken of the effective point of application of the horizontal acceleration forces. For stiff-masted cranes the point of application

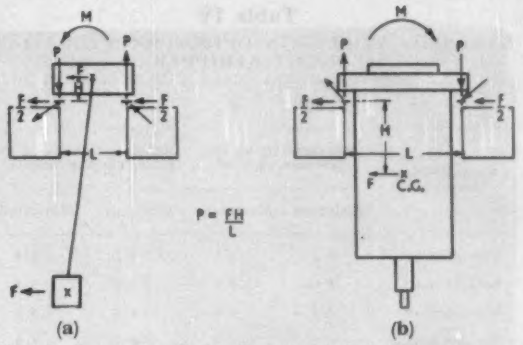

Fig. 3—Long-travel loadings: (a) hoist-rope crane; (b) stiff-masted crane

is at the centre of gravity of the crab and mast structure and may be several feet below the cross-travel rail at which the horizontal reaction occurs. A turning moment about the rail therefore results and vertical reactions on the rail occur which arise only to a much lesser extent in the movement of hoist-rope cranes. In hoist-rope cranes there is a small turning moment in the opposite sense to that applied to stiff-masted cranes due to the acceleration forces on the load being effectively applied at the level of the hoist drum, i.e. slightly above the rail level. For stiff-masted cranes the effect of the moment is to stress the top auxiliary members more highly than the bottom auxiliary members, while the reverse is true for hoist-rope cranes (*see* Fig. 3).

The conclusion is that the point of application of the acceleration forces must be considered for a true assessment of the long-travel loadings and stresses to be made. For simplicity, the inertia forces due to the self-weight of the girders have not been shown on Fig. 3, as these are common to all types of crane, but they must be considered in a complete statement of the long-travel inertia loadings.

Calculations have been made for the long-travel stresses set up in the stiff-masted cranes 5, 6, and 7 on the basis of these principles, and good agreement with measured values have been obtained. For example, the stresses in the bottom main and top and bottom auxiliary members of the ingot charger were calculated to be 0·8, 2·5, and 1·4 tons/in² respectively as compared with 0·6, 2·2, and 1·2 tons/in² measured (*see* Table III, columns 4, 5, and 6). The calculated stresses were only obtained by using one of the methods of stress analysis developed in the course of the investigation (p. 380), and some such reasonably comprehensive method is necessary for the adequacy of all parts of the structure to be checked. The assumption about the value of the acceleration forces is also important and was in accordance with clause 14 of the B.I.S.R.A. Specification (0·1 of the weight of the loaded mast and the girders).

Attention has so far been concentrated exclusively on the first of the causes of long-travel stresses, namely, acceleration (or deceleration) of the crane and load, and the importance of the unevenness of the track has not so far been considered. Emphasis has been given to acceleration forces because they, and their resultant actions, are largely calculable, and

Table IV

STRESSES ARISING IN OPERATIONS OF A 4-ton INGOT STRIPPER

1	2	3	4	5
Centre Panel Member	Measured Dynamic Stresses, tons/in²		Stresses Calculated for Crab-Tipping, tons/in²	
	Maximum	Minimum	Maximum	Minimum
Top main	−0·2	+0·9	−1·3	+1·4
Bottom main	+1·0	−3·0	+2·9	−3·4
Top auxiliary	−2·3	+3·8	−6·1	+5·4
Bottom auxiliary	+1·1	−1·2	+0·0	−1·0

Note: Stresses given above are superimposed on stress system due to mast at mid-span.
Sign Convention: + = tension.
− = compression.

to that extent under the control of the crane designer. This is not usually the case with regard to the state of the gantry track and the dynamic effects from this source are rather more difficult to estimate. They have, nevertheless, received considerable attention from a number of investigators, since it is possible that they may form, under extreme conditions, an appreciable proportion of the long-travel stresses. The conclusion, however, would appear to be that under average conditions the actual numerical values of the stresses from this form of loading are not high, and they are generally taken care of by designing to cover other effects such as snatch-hoisting (for hoist-rope cranes) and long-travel acceleration or deceleration (for both hoist-rope and stiff-masted cranes).

Ingot-stripping and Pit-scraping

In dealing so far only with dynamic effects arising from hoisting and long-travel motions, attention has been confined to effects which are generally recognized to occur frequently in the operation of E.O.T. cranes. It has therefore been accepted that cranes have to be designed to withstand such loadings safely. The imposition on steelworks cranes of other forms of dynamic loading is well known by all concerned with their operation, but great difficulty has been found in determining the extent to which the crane structure should be explicitly designed for such loadings. They may arise, for example, from mistaken overloads, shunting wagons, stripping stickers, scraping slag in soaking pits, or collisions between cranes on the same gantry.[6] According to Lightfoot,[2] the designer may allow for some measure of accidental misuse, especially if it occurs fairly often, but it is uneconomical to design a crane for infrequent abuses which cause high additional stressing (unless the user particularly requires it).

At the present time there are no British Standard Specifications that require cranes to be designed to withstand any forces other than those already discussed in connection with hoisting and long-travel motion. Even the latest British Standard Crane Specification (B.S. 2573 : 1955 " Maximum permissible stresses in crane structures ") does not distinguish between hoist-rope and stiff-masted cranes as such, in regard to the allocation of stress factors. The view of the present authors is that, to be realistic, certain loadings must be recognized as inevitably occurring in the course of the normal working of some types of steelworks cranes, in particular ingot strippers and chargers. It is thought that it is in the best interests of the operators and all concerned that the cranes should be appropriately designed for the duties involved. In the B.I.S.R.A. Specification opportunity is given for the purchaser to ask for the crane to be designed to withstand ' abnormal usage ', i.e. any dynamic loadings other than those generally recognized.

One of the tests in the present series was carried out on an ingot-stripping crane (5, Table I) and afforded an opportunity to observe the general-service loadings of this type of crane. With regard to direct vertical loading, for example, it was noted that when small quantities of steel had solidified round the base of moulds, owing to spillage during teeming, the vertical load on the tongs during stripping could easily be half the total weight of the bogie with the four ingots and moulds carried by it. This load could be, say, 25 tons compared with a design load of 8 tons and it would seem advisable to recognize that this loading will inevitably occur from time to time in the course of normal duties.

Stress records were taken during the stripping of an ingot and also while the crane was moving a train of loaded bogies, the latter operation being one that may be resorted to in difficult circumstances. In this case the loading is not vertical but horizontal and has a similar effect on the crane structure to that of the horizontal inertia arising in long-travelling (*see* Fig. 3). The average dynamic stresses recorded in the tests with the crab roughly central on the bridge are shown in Table IV. Comparison with Table III, columns 3–6, shows that the maximum stresses observed were about the same as those obtained in the long-travel tests. The maximum stress in a member has been taken to be the greatest dynamic stress which occured having the same sign as the stress produced in the member by simple vertical loading. Similarly, the minimum stress is the greatest dynamic stress occurring in the member having opposite sign to the static stress. In the operational tests, the minimum stresses were of greater magnitude than the maximum (Table IV, columns 2 and 3), showing that under the actual conditions of the test the greatest effects arose from the removal of load from the test girder. For comparison, columns 4 and 5 of Table IV show calculated stresses based on the assumption that the greatest dynamic effects that can occur on the girders are due to the crab being tipped entirely on to or off one bridge. This loading may occur only momentarily and the actual tipping of the crab be prevented by kick rollers, but it is suggested that a consideration of this action provides a means of estimating both the maximum horizontal and the maximum vertical loads that may be applied to the structure during the operation of this type of crane. The crab tipping condition also determines the loads on the mast.

Table IV shows that, in the particular test considered, this method of calculation gave a good indication of the *minimum* stresses occurring, and it

Table V
STRESSES ARISING IN OPERATIONS OF A 7-ton SOAKING-PIT CHARGER

1	2	3	4	5
Centre Panel Member	Measured Dynamic Stresses, tons/in²		Calculated for Oblique Load, tons/in²	
	Maximum	Minimum	Maximum	Minimum
Bottom main	+1·1	−1·1	+1·3	−1·1
Top auxiliary	−1·0	+1·5	−1·7	+1·3
Bottom auxiliary	+1·3	−0·9	+1·1	−1·1

Note: Stresses given above are superimposed on stress system due to mast over centre-line of soaking pits.
sign convention: + = tension
− = compression

Fig. 4—100-ton forging crane

may reasonably be inferred that on other occasions stresses approaching the calculated *maximum* stresses would be obtained. The mode of transmitting the horizontal loading to the crane structure is similar to that shown in Fig. 3 for the long-travel inertia forces, except that the point of application of the load F is at the level of the moulds moved and not at the centre of gravity of the mast. The magnitude of F is determined by the crab-wheel loading, the distance between crab rails, and the depth of the point of application of the load below the level of the crab rails.

A similar problem of estimating the possible dynamic forces arises for soaking-pit charger cranes, some of which have the duty of scraping the pit floors free of slag. Horizontal loading is then applied at the end of the spade held by the tongs and reaches a maximum value when the crab tipping condition occurs. As in the case of the particular test carried out, this condition may not always be reached and, even if reached, may not give rise to maximum stresses in all crane members owing to the soaking pits being placed towards one side of the mill building. The mast is well away from mid-span under these circumstances, with the result that even under maximum loading conditions a comparatively small bending moment is applied to the crane structure. Also, the maximum forces occurring at the spade may be applied obliquely to the crane owing to the rotary scraping action adopted and, hence, have only a limited effect on the crane bridge structure.

Some results are given in Table V to indicate the application of these principles to the 7-ton charger crane tested. The stresses given in columns 2 and 3 are the maximum and minimum recorded during about 7 min of pit scraping. The calculated stresses of columns 4 and 5 are those obtained on the assumption that the resultant load on the crane bridge had components of 4 tons parallel to the crane bridge and 2 tons at right-angles to it. These loads are such as nearly to cause oblique tipping of the crab, one of the wheel loads being reduced from 12 to 0·8 tons. The nature of the loading assumption is somewhat arbitrary, but the measure of agreement found be-

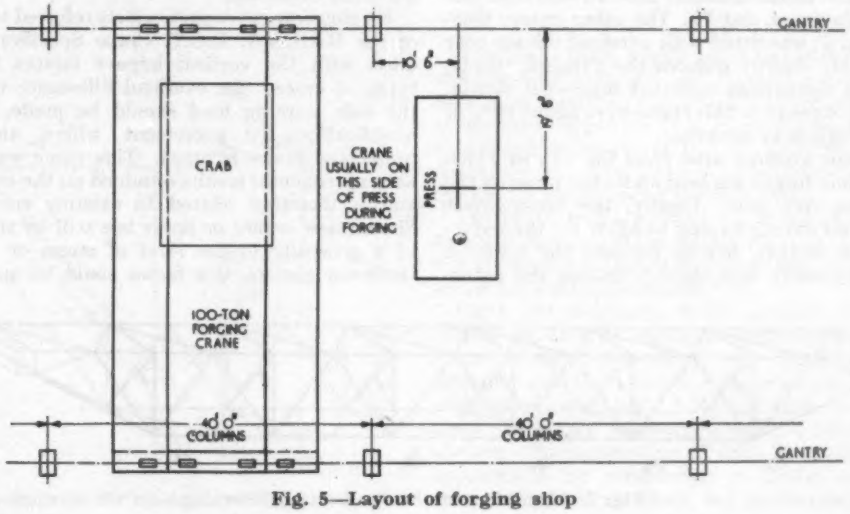

Fig. 5—Layout of forging shop

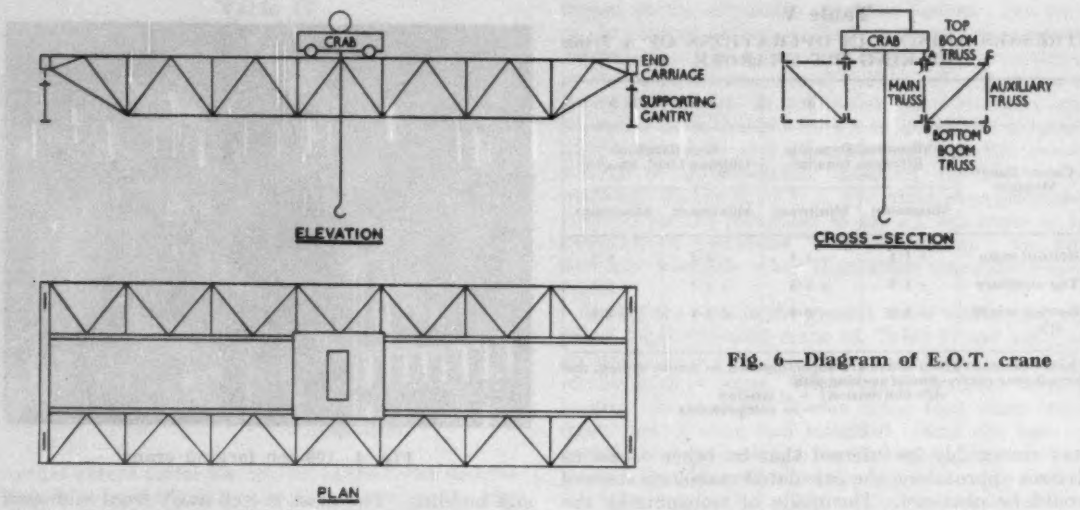

Fig. 6—Diagram of E.O.T. crane

tween the measured and calculated stresses would seem to indicate that loads of the order assumed occurred in the scraping operation.

It has therefore been shown that consideration of the mast forces required to tip the crab led to a reasonable estimation of the dynamic stresses in the case of the two cranes tested.

Forging

As forging cranes are operated in conjunction with presses capable of applying loads many times greater than the nominal crane safe working load, they constitute an obvious field for experimental investigation.

The stresses in two forging cranes were recorded in the present series of tests and, as shown in Table II, column 7, considerable dynamic effects were observed. In the case of the 250-ton crane operating in conjunction with a 7000-ton hydraulic press, the additional stresses imposed during forging were higher than those due to the nominal 250-ton safe load (*see* Table II, columns 4 and 7). The other crane, illustrated in Fig. 4, was fitted with overload release gear which probably slightly reduced the dynamic effects, although the mechanism operated somewhat slowly. The dynamic stresses in this crane were about 80% of the nominal safe-load stresses.

The dynamic loadings arise from the way in which the ingots being forged are held under the press by the crane turning-over gear. Ideally, the turning-over gear is lowered during forging to allow for the reduction in ingot section, but in practice the lowering movement generally lags slightly behind the action of the press and some press load is taken by the crane. The crane dynamic loading arises from an imposed additional deflection and is therefore very much dependent on the stiffness, not only of the crane structure, but also of the particular gantry girder supporting the crane. Maximum dynamic effects on the crane will therefore occur when the press is so situated that the crane is over or near a stanchion when holding the ingot under the press. As shown in Fig. 5, a comparatively unfavourable situation occurred in the case of the 100-ton crane tested. For the crane to be in a suitable position for forging, say 10 ft away from the press, the end-carriages would be located in the immediate vicinity of the gantry columns. Thus a minimum of flexibility was derived from the gantry under overload conditions. It is also to be noted that in this case the effective crane stiffness is increased by the forge being off-centre with respect to the crane bridge. All these factors should be considered in the design of new plant in order to minimize overloads.

Forging cranes are particularly referred to in Table I of the B.I.S.R.A. E.O.T. Crane Specification which deals with the vertical impact factors for various types of crane. An overload allowance of 100% of the safe working load should be made, subject to modification by agreement where an overload protective device is fitted. This value was based on the experimental results obtained on the cranes tested and is therefore related to existing crane designs. Should new cranes be made less stiff by the adoption of a generally higher level of stress or the use of shallower girders, this factor could be appropriately

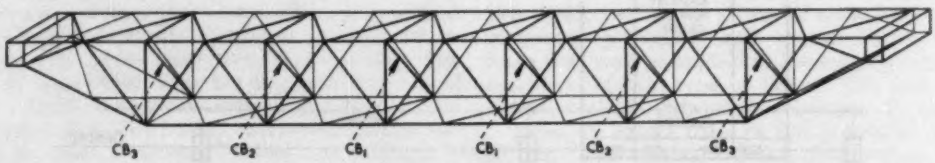

Fig. 7—Typical crane-bridge lattice girder

reduced, and similarly the adoption of lower stress levels or deeper girders would require a greater allowance for overloads to be made.

DESIGN METHODS

General

Design methods which neglect the effect of live loading on the auxiliary girder are generally used for simplicity, but a method which involves the consideration of the box section as a whole is necessary if it is desired to make full use of the permissible stresses throughout the structure.

Figure 6 shows the E.O.T. crane structure, consisting of two girders of the type shown in Fig. 7. The bridge girder is braced on all four sides and cross-braced at the panel points. The main girder may be of the plated type but it is nevertheless possible for simplicity to treat the structure as:

(*a*) A space frame, with pin joints throughout;
(*b*) A composite beam, consisting essentially of the four chords *A*, *B*, *C*, and *D* forming an unsymmetrical section in bending (Fig. 6); or
(*c*) A number of component trusses or beams,[7] which is basically a particular treatment of (*a*).

Characteristics of a Triangular Girder

It will be useful to consider first a triangular girder braced on all three sides, as shown in cross-section in Fig. 8.

For a simply supported span, the loads *W* and *F* applied to the rail will cause moments M_X and M_Y about the *XX* and *YY* axes respectively, together with a torque *T* about the longitudinal axis.

For equilibrium the forces in the three chords *A*, *B*, and *C* will resist the applied moments M_X and M_Y.

Let suffixes *A*, *B*, and *C* refer to the three chords respectively and let *P* be the member loads and *A* the cross-sectional areas; then:

$$\left.\begin{array}{l}\text{Taking moments about } AC \\ \text{parallel to plane } YY\end{array}\right\} P_B = \frac{M_X}{d} \text{ tension}$$

$$\left.\begin{array}{l}\text{Taking moments about } AB \\ \text{parallel to plane } XX\end{array}\right\} P_C = \frac{M_Y}{b} \text{ tension}$$

and it follows that for equilibrium of the cross-section

$$P_A + P_B + P_C = 0$$

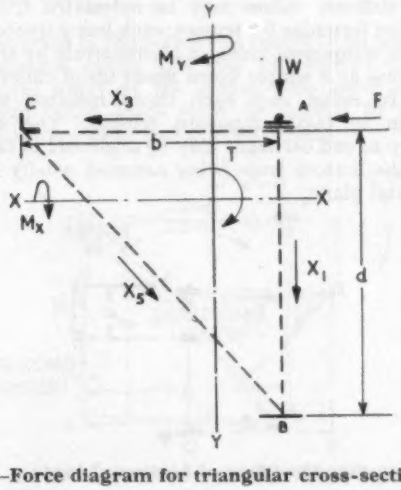

Fig. 8—Force diagram for triangular cross-section

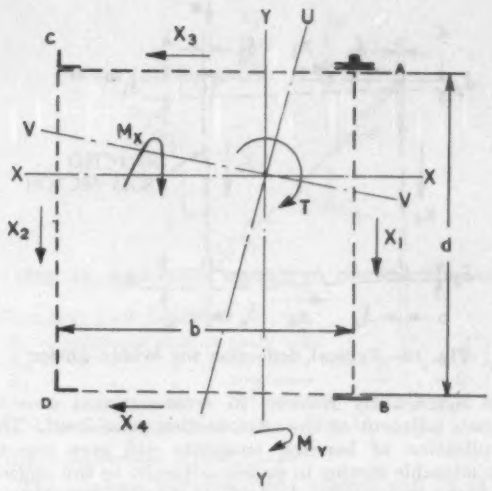

Fig. 9—Force diagram for rectangular cross-section

i.e. $$P_A = -\left(\frac{M_X}{d} + \frac{M_Y}{b}\right) \text{compression.}$$

Hence the forces in the chords are determined directly from the moments M_X and M_Y and the system is statically determinate. The shears X_1, X_3, and X_5 may also be found by the application of statics, and it will be observed that it is not necessary to designate a value to the torque *T*.[8]

The above theory applies whether the girder is treated by method (*a*), (*b*), or (*c*). The space frame method (*a*) indicates that the shear X_5 is zero. Hence $X_1 = W$ and $X_3 = F$ approximately, the main girder carrying the vertical rail load and the top truss the horizontal rail load.

Characteristics of Box Girder in Current Use

Using the notation as previously, and referring to Fig. 9,

$$M_X = P_D d + P_B d$$
$$M_Y = P_C b + P_D b$$

and $$P_A + P_B + P_C + P_D = 0.$$

The above three equations of statics do not allow a solution for P_A, P_B, P_C, and P_D, and one of the chords may be regarded as redundant. Alternatively, in the space-frame approach it is more convenient to consider the cross bracings CB_1, CB_2, and CB_3 in Fig. 7 as redundancies. Any method of solution will involve the elastic properties of the structure.

The space frame method (*a*) is laborious and unsuited to drawing office use, and its use suggests that it is no more accurate than other simplified methods which have been developed.[7]

Using the composite beam method (*b*), the four chords are taken as forming a composite beam and the simple theory of bending may be applied about principal axes *UU* and *VV*. This is accepted as giving engineering accuracy,[8, 9] although the bending theory is derived assuming a beam of constant cross-section. The significance of this assumption may be appreciated by considering a girder cross-section where two chord members, say auxiliaries A_C and A_D,

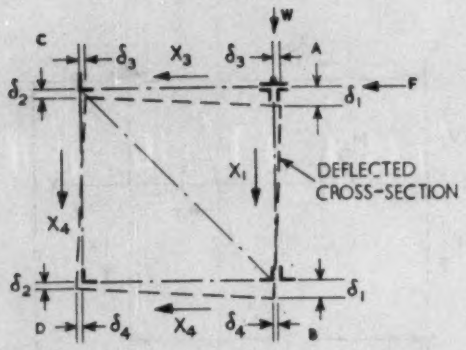

Fig. 10—Typical deflection for bridge girder

are significantly reduced in cross-sectional area in panels adjacent to the cross-section considered. The application of bending moments will give rise to considerable strains in panels adjacent to the section and the stresses in A_C and A_D would, in practice, be considerably less at this section than those given by the simple theory of bending based on cross-sectional areas.

Hence the problem is one of elastic deformation. It can be shown, however, that once a set of chord stresses has been decided on, either by simple bending about principal axes or by some other device, the shears X_1, X_2, X_3, and X_4 in the four trusses may be determined by statical consideration only.[8] It is again not necessary to designate a value to the torque T, although it may be convenient to do so.

Deflection Method of Design for Crane Girders

This is a method of type (*c*) and was developed in 1953, early in this series of crane tests. It may be put forward as a method which attempts to take into account an elastic deformation of the entire bridge girder, and, applied to the case of the crab in the central position, is an accurate solution of the structure shown in Fig. 7, with the cross bracings CB_2 and CB_3 on either side of the loaded cross-section removed. Thus loads are considered to be transferred to the auxiliary structure by means of two cross-bracings only, this assumption being justified by the crab-wheel spacings being normally approximately one panel length. Application of the full space-frame theory to one crane tested and to similar structures[10] indicates that the forces in the bracings CB_2, CB_3 will be small.

Figure 10 shows the deflected crane cross-section which, when subjected to the rail loads W and F, undergoes both vertical and lateral displacements together with a twist, the cross-bracings BC maintaining the original rectangular cross-section very closely.

It is considered that each of the truss (or shear) loads X acting in the plane of its own particular truss, assumed supported at the end carriages, will produce the appropriate deflection δ in its own plane.

A load W acting at the rail may be replaced by an equal force W' acting parallel to W at a distance e from it, together with a couple We twisting the girder (Fig. 11). The value of e is such that the load W' acting alone produces equal vertical deflections of the main and auxiliary trusses.

A lateral force F may be treated in a similar way, being replaced by an equal force F' acting parallel to F and distance h from it, together with a couple Fh twisting the girder. The value of h is such that the load F' acting alone produces equal horizontal deflections of the top and bottom booms (*see* Fig. 12).

Magnitude of Truss Loads without Torque

When W and F act together, the principle of superposition may be applied.

Let W_1 be the load in the main truss due to W'
W_2 " " " " " auxiliary truss due to W'
F_3 " " " " " top truss due to F'
F_4 " " " " " bottom truss due to F'
with corresponding girder stiffnesses m_1, m_2, m_3, and m_4 tons/in. deflection respectively; then:

$$W_1 = W'\frac{m_1}{m_1+m_2} = W\frac{m_1}{m_1+m_2} \quad \text{.....(1)}$$

$$W_2 = W'\frac{m_2}{m_1+m_2} = W\frac{m_2}{m_1+m_2} \quad \text{.....(2)}$$

$$F_3 = F'\frac{m_3}{m_3+m_4} = F\frac{m_3}{m_3+m_4} \quad \text{.....(3)}$$

$$F_4 = F'\frac{m_4}{m_3+m_4} = F\frac{m_4}{m_3+m_4} \quad \text{.....(4)}$$

Also $$e = b\frac{m_2}{m_1+m_2} \quad \text{..... (5)}$$

$$h = d\frac{m_4}{m_3+m_4} \quad \text{..... (6)}$$

where b and d are the girder breadth and depth respectively.

The stiffness values may be calculated from the deflection formulae for trusses, each being treated as a separate component truss, or alternatively by treating each truss as a simple beam made up of chord areas only. In either case each chord member will be common to two component trusses. The normal slope up to end carriages may be neglected in calculations, the bottom truss being assumed wholly in one horizontal plane.

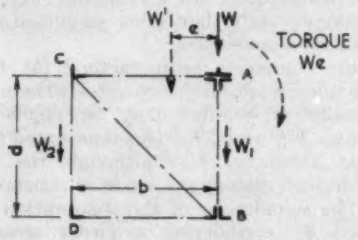

Fig. 11—Effect of vertical load

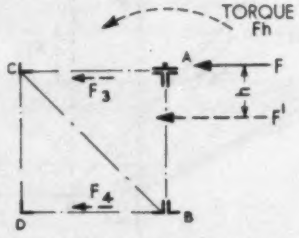

Fig. 12—Effect of horizontal load

Magnitude of Truss Loads Due to Torque

The effect of the torque T is shown in Fig. 13, where P = force in main and auxiliary trusses and Q = force in top and bottom trusses.

It is assumed that P and Q will produce simple bending of the four trusses; then

$$T = Pb + Qd = We - Fh$$

Let the girder rotate through α radians, about some centre O, distant e' horizontally and h' vertically from the rail member.

Then :

Force in main truss $= P = \alpha e' m_1$
" " auxiliary " $= P = \alpha(b - e')m_2$
" " top boom " $= Q = \alpha h' m_3$
" " bottom boom " $= Q = \alpha(d - h')m_4$

$$\therefore \alpha e' m_1 = \alpha(b - e')m_2$$

whence $$e' = \frac{m_2}{m_1 + m_2} \times b = e$$

Likewise

$$h' = \frac{m_4}{m_3 + m_4} d = h$$

Also $$T = Pb + Qd$$

$$= \alpha e m_1 \times b + \alpha h m_3 \times d$$

$$= \alpha \left\{ \frac{m_2 b}{m_1 + m_2} \right\} m_1 b + \alpha \left\{ \frac{m_4 d}{m_3 + m_4} \right\} m_3 d$$

$$= \alpha \frac{m_1 m_2}{m_1 + m_2} b^2 + \alpha \frac{m_3 m_4}{m_3 + m_4} d^2$$

$$\therefore \alpha = \frac{T}{\frac{m_1 m_2}{m_1 + m_2} b^2 + \frac{m_3 m_4}{m_3 + m_4} d^2}$$

Substitute in values for P and Q

$$P = \frac{Tem_1}{\frac{m_1 m_2}{m_1 + m_2} b^2 + \frac{m_3 m_4}{m_3 + m_4} d^2}$$

$$Q = \frac{Thm_3}{\frac{m_1 m_2}{m_1 + m_2} b^2 + \frac{m_3 m_4}{m_3 + m_4} d^2}$$

or $$P = \frac{(We - Fh)em_1}{D} \quad \text{.....(7)}$$

and $$Q = \frac{(We - Fh)hm_3}{D} \quad \text{.....(8)}$$

where $$D = \frac{m_1 m_2 b^2}{m_1 + m_2} + \frac{m_3 m_4 d^2}{m_3 + m_4}$$

The trace of the rotational centre O parallel to the longitudinal girder axis may be referred to as the 'flexural axis' of the girder, this being the axis through which loads must be applied in order to produce zero twist on the cross-section.[11]

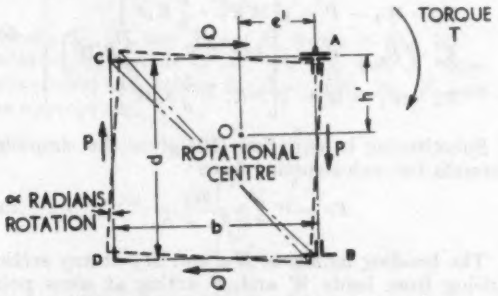

Fig. 13—Rotation under torque loading

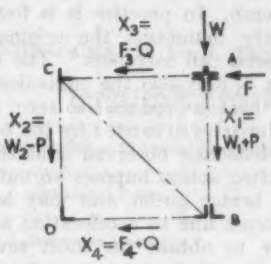

Fig. 14—Equivalent loading on the four trusses

Resultant Live Loads on Trusses

$$\left.\begin{array}{ll} X_1 = \text{resultant load on main truss} & = W_1 + P \\ X_2 = \text{" " " auxiliary truss} & = W_2 - P \\ X_3 = \text{" " top truss} & = F_3 - Q \\ X_4 = \text{" " bottom truss} & = F_4 + Q \end{array}\right\} \quad (9)$$

These loadings are shown in Fig. 14.

Girder Self-weight Truss Loads

The analysis for girder self-weights will be as for live loads above. The girder self-weight and centre of gravity position should be determined and the load transferred to the rotational centre O, together with an appropriate torque on the girder. Additional truss loads X_1, X_2, X_3, and X_4 may then be determined and added to those due to live loads above.

In practice the torque due to dead loads may be neglected when the girder centre of gravity is near the rotational centre O.

Forces in Members

The trusses may be analysed for the loads X_1, X_2, X_3, and X_4, determined with the crabs in the central position (treated as rolling loads for design purposes). Checks on existing cranes show that the calculated stresses are least reliable with the crab near the end stops, presumably owing to the considerable fixities present.

Chord member stresses will be obtained by superposition of the effects of two adjacent trusses in each case.

The force transferred by the cross-bracings CB, normally carried by a pair, may be taken as

$$\sqrt{(X_2^2 + X_4^2)}.$$

Strutting Action of Crab

Under the action of vertical load at the rail member, the deflection of the girder will be somewhat as shown in Fig. 10. The rail member is displaced inwards

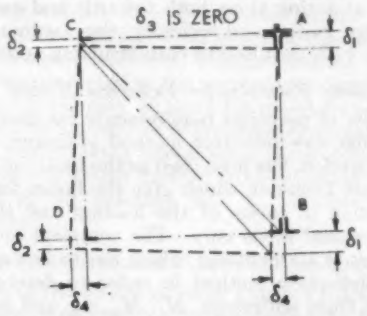

Fig. 15—Deflection with full crab strutting action

towards the crab. In practice it is found that the crab frequently maintains the original horizontal distance between rail members.[7] The deflection of the top boom δ_3 and also the equivalent loading in its plane are therefore reduced to zero, the whole of the strutting force being carried by the bottom boom. The type of deflection observed is as shown in Fig. 15. The strutting action imposes an outward lateral force on the bridge girder and may be considered with lateral forces due to acceleration and deceleration in order to obtain the most severe loading conditions.

Value of Strutting Force

Let a vertical load W be applied at the rail member

and let X_3' = force in top boom with no crab strutting action

then $X_3' = Q'$

where Q' is the torque component given by equation (8) with $T = We$

$$\therefore \quad X_3' = \frac{Wehm_3}{D}$$

Let Fs = lateral force on girder due to crab strutting action

X_3'' = force in top boom due to crab strutting action only

$= F_3'' + Q''$

where F_3'' = direct load in top boom due to Fs given by equation (3)

and Q'' = torque component due to Fs given by equation (8) with $T = Fsh$

$$\therefore \quad X_3'' = Fs \times \frac{m_3}{m_3 + m_4} + \frac{Fsh^2m_3}{D}$$

For the load in the top boom X_3' to be reduced to zero by crab strutting action $X_3' = X_3''$

i.e.

$$\frac{Wehm_3}{D} = Fs \times \frac{m_3}{m_3 + m_4} + \frac{Fsh^2m_3}{D}$$

$$Fs = \frac{Weh(m_3 + m_4)}{D + h^2(m_3 + m_4)} \qquad \text{.....(10)}$$

Since the setting up of the strutting force depends on binding friction between the crab wheels and the rails, movement of the crab will tend to reduce the magnitude of the strutting force, the girder being free to rotate to take up its natural deflection under vertical loading.

In design, the maximum resultant boom forces may be obtained by considering, first, the live lateral loading as acting alone both towards and away from the bridge girder, and secondly, this loading in combination with that due to crab strutting action.

Approximate Formulae for Deflection Method

In view of practical requirements for simplicity of calculation, the deflection method of design, itself an approximation, has been used as the basis for developing simple formulae which give the boom forces in a box section in terms of the loading and the boom cross-sectional areas only. The complete analysis of the forces in all members, which has to be carried out in the deflection method in order to determine the value of truss stiffnesses, M_1, M_2, m_3, and m_4, is not required, with a resulting saving in time of calculation.

In the approximate method of analysis all four trusses are treated as simple beams made up of two chord members only, the effect of bracings being neglected; hence

$$m_1 \propto I_1$$
$$m_2 \propto I_2$$
$$m_3 \propto I_3$$
$$m_4 \propto I_4$$

where I_1, I_2, I_3, and I_4 are the respective second moments of area.

Let b and d be the breadth and depth of the box girder respectively.

Then

$$I_1 = \frac{A_A A_B}{A_A + A_B} d^2$$

$$I_2 = \frac{A_C A_D}{A_C + A_D} d^2$$

$$I_3 = \frac{A_A A_C}{A_A + A_C} b^2$$

$$I_4 = \frac{A_B A_D}{A_B + A_D} b^2$$

where A refers to cross-sectional area and the suffixes to respective chord members.

Let

$$C = A_A A_B A_C + A_A A_B A_D + A_A A_C A_D + A_B A_C A_D$$
$$K_1 = A_A A_B (A_C + A_D)/C$$
$$K_2 = A_C A_D (A_A + A_B)/C$$
$$K_3 = A_A A_C (A_B + A_D)/C$$
$$K_4 = A_B A_D (A_A + A_C)/C$$

Then, the truss loadings due to bending W_1, W_2 and F_3, F_4 (*see* Figs. 11 and 12) are given by:

$$W_1 = K_1 W \text{ and } W_2 = K_2 W \quad \text{.....(1a) (2a)}$$
$$F_3 = K_3 F \text{ and } F_4 = K_4 F \quad \text{.....(3a) (4a)}$$

Also $e = K_2 b$ and $h = K_4 d$ .....(5a) (6a)

The truss loads due to torque P and Q (*see* Fig. 13) may be shown to be:

$$P = \frac{WbK_2 - FdK_4}{2b} \qquad \text{.....(7a)}$$

$$Q = \frac{WbK_2 - FdK_4}{2d} \qquad \text{.....(8a)}$$

The torque is resisted equally by the vertical trusses AB, CD and the horizontal trusses AC, CD.

Also combining the loads due to bending and torque gives:

$$\left.\begin{aligned} X_1 &= W_1 + P = \tfrac{1}{2}\left[W(1 + K_1) - \frac{d}{b}K_4F\right] \\ X_2 &= W_2 - P = \tfrac{1}{2}\left[WK_2 + \frac{d}{b}K_4F\right] \\ X_3 &= F_3 - Q = \tfrac{1}{2}\left[F(1 + K_3) - \frac{d}{b}K_3W\right] \\ X_4 &= F_4 + Q = \tfrac{1}{2}\left[FK_4 + \frac{b}{d}K_3W\right] \end{aligned}\right\} \text{...(9a)}$$

Substituting in equation (10) gives the simplified formula for crab strutting force

$$Fs = W\frac{b}{d}\frac{K_2}{(2K_3 + K_4)} \qquad \text{.....(10a)}$$

The bending moments M_W and M_F at any section arising from loads W and F acting at some point along the crane girder may be taken as kW and kF,

Table VI

CALCULATED AND MEASURED STRESSES—250-ton FORGING CRANE (No. 1, Table I)

Crane Details:

Span 70 ft. Lattice construction with five 14 ft panels. Date of manufacture: 1937. Effective breadth of girders = 5·92 ft.
Effective depth of main girders = 7·29 ft. Effective depth of auxiliary girder = 6·25 ft. Date of Test: April, 1953.

Member			Vertical Load per Girder = 52·5 tons, 8 ft off Centre					
			Measured Values	Calculated Values				Office Method (All Load on Main Girder) Drawing
				Deflection Method				
				Approximate		Full		
Location		Area, in²		Without Crab Strutting Action	With Crab Strutting Action	Without Crab Strutting Action	With Crab Strutting Action	
Direct Stresses, tons/in²								
Top main (including rail)		136·2	− 0·7	− 0·7	− 0·7	− 0·7	− 0·7	− 0·7
Bottom main		78·5	+ 1·0	+ 1·2	+ 1·1	+ 1·1	+ 1·1	+ 1·2
Top auxiliary		4·75/11·6	− 0·2	− 0·4	− 0·2	− 0·5	− 0·3	0·0
Bottom auxiliary		3·75/7·5	+ 0·7	+ 0·6	+ 0·8	+ 0·7	+ 1·0	0·0
Main girder bracing second panel from end		30·3	− 1·3	...	...	− 1·4	− 1·4	− 1·5
Auxiliary girder bracing second panel from end		3·25	− 0·4	...	...	− 0·2	− 0·3	0·0
Cross-bracing between main and auxiliary girders at centre panel point directly under crab	In compression	2·11	0·0	...	...	− 0·2	− 0·3	0·0
	In tension	2·11	+ 0·2	...	...	+ 0·2	+ 0·3	0·0
Deflections, in. (Dial Gauge Readings)								
Main girder			0·180	...	...	0·183	0·182	0·185

where k is a constant depending on the position of the loads. Similarly, bending moments due to truss loads X_1, X_2, X_3, and X_4 may be taken as kX_1, kX_2, kX_3, and kX_4, since these will act as the same position as Q and F.

Let the forces in the four chord members at any section be p_A, p_B, p_C, and p_D.

Then :

$$p_A = -k\left(\frac{X_1}{d} + \frac{X_3}{b}\right)$$

$$p_B = +k\left(\frac{X_1}{d} - \frac{X_4}{b}\right)$$

$$p_C = -k\left(\frac{X_2}{d} - \frac{X_3}{b}\right)$$

$$p_D = +k\left(\frac{X_2}{d} + \frac{X_4}{b}\right)$$

where X_1, X_2, X_3 and X_4 act as shown in Fig. 10.

Substituting values of X_1, X_2, X_3, and X_4 from equations (9a) and writing in values of W_1, W_2, F_3, and F_4 as appropriate,

$$p_A = -k\left(\frac{W_1}{d} + \frac{F_3}{b}\right)$$

$$p_B = +k\left(\frac{W_1}{d} - \frac{F_4}{b}\right)$$

$$p_C = -k\left(\frac{W_2}{d} - \frac{F_3}{b}\right)$$

$$p_D = +k\left(\frac{W_2}{d} + \frac{F_4}{b}\right)$$

Evidently, by the above approximate analysis the forces in the chord members are independent of the torque, since the torque terms cancel out. The most useful form of the equations is probably in terms of the bending moments, M_W and M_F, and the constants K_1, K_2, K_3, and K_4 as follows:

$$\left.\begin{aligned} p_A &= -\frac{K_1}{d}M_W - \frac{K_3}{b}M_F \\ p_B &= +\frac{K_1}{d}M_W - \frac{K_4}{b}M_F \\ p_C &= -\frac{K_2}{d}M_W + \frac{K_3}{b}M_F \\ p_D &= +\frac{K_2}{d}M_W + \frac{K_4}{b}M_F \end{aligned}\right\} \quad \ldots\ldots\ldots(11a)$$

Girder self-weights may be allowed for by calculating M_W to include the total effect of the rail and girder self-weight moments, torques due to girder weights being neglected in the approximate analysis.

Equations (11a) may be used for chord forces and hence for chord stresses in a preliminary design, the value of M_F used taking into account the moment due to crab strutting action derived from equation (10a). The shears in the bracings may be obtained from equations (9a).

Comparison between Measured and Calculated Stresses

A number of results are given in Tables VI–IX comparing stresses measured in existing steelworks E.O.T. crane structures with those calculated using the full

Table VII

CALCULATED AND MEASURED STRESSES—100-ton FORGING CRANE (No. 2, Table I)

Crane Details:

Span 53 ft 6 in. Plate main girders. Lattice auxiliaries. Date of Manufacture: 1948.
Effective depth of box and main girders = 5·60 ft.
Effective breadth of girder = 5·42 ft.
Date of Test: April, 1954.

Member			Vertical Load per Girder = 45·5 tons at centre					
			Measured Values	Calculated Values				Drawing Office Method (All Load on Main Girder)
				Deflection Method				
				Approximate		Full		
Location		Area, in²		Without Crab Strutting Action	With Crab Strutting Action	Without Crab Strutting Action	With Crab Strutting Action	
Direct Stresses, tons/in²								
Top main (including rail)		51·60	− 1·7	− 1·5	− 1·7	− 1·6	− 1·6	− 1·7
Bottom main		39·35	+ 1·7	+ 2·0	+ 1·8	+ 2·1	+ 2·0	+ 2·2
Top auxiliary		4·50	− 0·7	− 1·5	− 0·9	− 1·2	− 0·9	0·0
Bottom auxiliary		3·25	+ 1·4	+ 2·0	+ 2·6	+ 1·6	+ 2·4	0·0
Auxiliary girder bracing	End panel	3·25	+ 1·0	...	...	+ 0·6	+ 1·0	0·0
		2·49	+ 0·3	...	...	+ 0·2	+ 0·2	0·0
	Panel adjacent to end panel	2·49	− 0·2	...	...	− 0·4	− 0·6	0·0
Bottom boom bracing	End panel	2·11	+ 0·3	...	...	+ 0·4	+ 0·6	0·0
		2·11	0·0	...	...	− 0·4	− 0·6	0·0
Deflections, in. (Dial Gauge Readings)								
Main girder			0·161			0·186	0·183	0·192

Table VIII

CALCULATED AND MEASURED STRESSES—5-ton OVERHEAD BOX CHARGER (No. 7, Table I)

Crane Details:

Span 63 ft 7 in. Plate main girders. Lattice auxiliaries.
Effective depth of box and main girders = 5·58 ft.
Effective breadth of wide side of crane = 6·15 ft; of narrow side = 4·4 ft.
Date of Test: August, 1953.

Member		Vertical Load per Girder = 6·08 tons, at Centre						
		Wide Side			Narrow Side			
		Measured Values	Calculated Values		Measured Values	Calculated Values		Drawing Office Method. Both Sides. All load on Main Girder
			Deflection Method Without Crab Strutting Action			Deflection Method Without CrabStrutting Action		
Location	Area in²		Approximate	Full		Approximate	Full	
Direct Stresses, tons/in²								
Top main	14·86	− 0·7	− 0·9	− 0·9	− 0·7	− 0·9	− 0·9	− 1·1
Bottom main	14·86	+ 0·8	+ 0·9	+ 0·9	+ 0·8	+ 0·9	− 0·9	+ 1·1
Top auxiliary	4·75*	− 0·2	− 0·7	− 0·5	− 0·2	− 0·7	− 0·5	0·0
Bottom auxiliary	6·63/3·25	+ 0·3	+ 0·5	+ 0·3	+ 0·5	+ 0·5	+ 0·4	0·0
Deflections, in.								
Main Girder		Not measured		0·266				0·290

* Area supported by floor plates.

Table IX

CALCULATED AND MEASURED STRESSES—5-ton MAGNET CRANE (No. 10, Table I)

Crane Details:

Span 56 ft 3$\frac{11}{16}$ in. Lattice construction with seven 8-ft panels. Date of manufacture: 1951. Effective breadth of girders = 4·44 ft.
Effective depth of main girders = 4·33 ft. Effective depth of auxiliary girders = 4·08 ft. Date of Test: November, 1952.

Member		Vertical Load per Girder = 3·75 tons, at Centre					
			Calculated Values				
			Deflection Method				Drawing Office Method. All load on main girder
			Without Crab Strutting Action		With Crab Strutting Action		
Location	Area in²	Measured Values	Approximate	Full	Approximate	Full	
Direct Stresses, tons/in²							
Top main	11·2*†	− 0·3‡	− 0·7	− 0·8	− 0·8	− 0·8	− 0·9
Bottom main	5·72	+ 1·6‡	+ 1·6	+ 1·7	+ 1·4	+ 1·5	+ 2·0
Top auxiliary	2·49†	− 0·1‡	− 1·0	− 0·7	− 0·6	− 0·6	0·0
Bottom auxiliary	2·49	+ 0·8‡	+ 1·0	+ 0·7	+ 1·3	+ 1·1	0·0
Cross bracings at crab	1·46	0‡	+ 0·2	+ 0·2	+ 0·3	+ 0·2	0·0
Deflections, in. (Dial Gauge Readings)							
Main girder		0·190	0·153	0·180	0·144	0·170	0·195
Auxiliary girder		0·104	0·064	0·052	0·084	0·084	0·0
Top boom		0·006	0·036	0·037	0	0	0·0
Bottom boom		0·078	0·043	0·057	0·055	0·078	0·0

* Includes area of rail section.
† Floor plates riveted to these members giving effectively greater section area.
‡ Not true direct stresses, Individual strain gauge reading only, probably including slight secondary stresses.

and approximate deflection methods of design with and without the effect of crab strutting action.

Comparison is also made in the last column of each Table with the calculated stresses arising from the generally used drawing office method, in which all the vertical loading is assumed to be carried by the main girder only.

With regard to the main girders, the results from the several calculation methods differ only slightly between themselves and are fairly close to the measured values. As might be expected, the calculated stresses for the auxiliary girder members are more susceptible to differences in method and assumptions regarding crab strutting action. The approximate formulae nevertheless appear to give sufficient accuracy for checking the stresses in any given design, although the actual stresses in the completed structure may be affected by local features such as the attachment of walkways, long-travel gear mountings, etc.

Dynamic Considerations

Neglecting losses, the work done by a shock or impact loading on a crane will be absorbed as strain energy within the elastic system comprising ropes, crab, bridge, and gantries. For a structure subjected to load, the strain energy stored in the material due to direct stresses is given by

$$\sum f^2/2E \times \text{volume of material},$$

where f is the value of the stress reached and E is Young's modulus for the material. Similar expressions may be derived for members subjected to bending, shear, or torsion, and the total strain energy may be equated to the work done by the impact loading. Should many parts be substantially understressed below the permissible, either by initial inadequate design or subsequent addition to the structure, the capacity of the structure as a whole to absorb strain energy is reduced. The effect of the shock loading will be concentrated on the more highly stressed parts of the structure and higher impact stresses will be reached than in a structure designed to the same stress level throughout.

An example occurs in the case of cranes where the floor or rail is riveted to the upper bridge members after these have been designed to carry the compression loads at their appropriate permissible stresses. The resulting fall in stress lowers the energy absorption and failure will occur in the lower tension members at a reduced value of impact loading. The structure is not strengthened against dynamic loading by the addition of material in this way.

The riveting down of floor or rail appears to be a procedure of doubtful value as after the removal of these parts for any reason the rivets may not all be replaced. If it is decided to make use of the floor or rail as load-carrying members the effect on the design should be checked, an appropriate fraction (generally $\frac{1}{3}$) of the area of the floor plates being added to the area of the chord members. It remains true, however,

Table X

STRESS RANGES IN LATTICE-GIRDER CRANES

1	2	3	4	5	6	7	8	9	10
Crane	Truss Member	Cross-Sectional Area, in²	Crab Position for Minimum Stress	Minimum Stress f_{min}, tons/in²	Crab Position for Maximum Stress	Maximum Stress f_{max}, tons/in²	Ratio Stress f_{min}/f_{max}	Mean Stress, tons/in²	Stress Range, tons/in²
16-ton grabbing Crane	Top main	27·30	Slightly off-centre (loaded)	− 1·1	Wheel over gauge (loaded)	+ 3·6	− 0·30	+ 1·2	4·7
	Bottom main	18·20	At end (unloaded)	+ 2·3	Slightly off-centre (loaded)	+ 4·6	+ 0·50	+ 3·5	2·3
	Top auxiliary	3·82	At end (unloaded)	− 1·5	Central (loaded)	− 3·1	+ 0·48	− 2·3	1·6
	Bottom auxiliary	3·03	At end (unloaded)	+ 2·2	Central (loaded)	+ 4·5	+ 0·48	+ 3·3	2·3
	Centre bay diagonal	6·50	Minimum shear (loaded)	+ 1·3	Maximum shear (loaded)	− 2·0	− 0·65	− 0·3	3·3
	Adjacent bay diagonal	7·79	Minimum shear (loaded)	+ 0·1	Maximum shear (loaded)	− 2·4	− 0·04	− 1·2	2·5
100-ton Ladle crane	Top main	54·1	Wheel over gauge (loaded)	+ 2·0	Slightly off-centre (loaded)	− 2·9	− 0·69	− 0·4	4·9
	Bottom main	48·2	At end (unloaded)	+ 0·8	Slightly off-centre (loaded)	+ 3·8	+ 0·21	+ 2·3	3·0
	Centre bay diagonal	8·7	Minimum shear (loaded)	+ 2·2	Maximum shear (loaded)	− 4·2	− 0·52	− 1·0	6·4
	Adjacent bay diagonal	13·8	Minimum shear (unloaded)	+ 0·5	Maximum shear (loaded)	+ 3·9	+ 0·13	+ 2·2	3·4

Note: The stresses shown do not include any dynamic impact effects.

that great care must be subsequently exercised to ensure that the structure is properly maintained.

Should a particularly stiff crane be required, the working stresses should be lowered throughout to a constant fraction of the normal permissible stresses, giving effectively greater strength throughout.

PERMISSIBLE STRESSES

The third essential of correct design, appropriate permissible stresses, is a vital point on which very little precise information is available at present, as few tests to failure have been carried out on fabricated structures subjected to fluctuating loads. The design of steelworks cranes has been guided generally by British Standard Specification 466 : 1947, although this is intended primarily for light service cranes. Other types are covered by a clause requiring an increase of 25% in the safety factor for cranes subject to severe duties or accidental overloads. This specification does not distinguish between the different duties of steelworks cranes, and it also only considers load fluctuations sufficiently great to cause stress reversal in individual structural members. An attempt to take all aspects into account has been made in the B.I.S.R.A. Specification for Heavy Duty E.O.T. Cranes in Iron and Steel Works (1955). This Specification distinguishes between the vertical dynamic factors for ingot handling, plate-handling, grab and magnet cranes, forging cranes, and ladle cranes and also includes, in a shortened form, fatigue factors based on the ratio of extreme stresses which have been proposed for the Draft Revision of B.S. 153 (Girder Bridges, Part 3, Loads and Stresses).

Another British Standard, " Report on Permissible Stresses in Crane Structures " (B.S. 2573 : 1955) has also recently endeavoured to distinguish between different types of crane and to take account of fatigue, and is to be welcomed as encouraging closer consideration of individual crane duties and loadings. The form of classification and the actual factors adopted appear, however, to be somewhat arbitrary. In introducing the concept of fatigue it is realized that in most cases of large buildings, etc., the magnitude and frequency of the loading fluctuations are not sufficiently great for fatigue to affect the average working life of the structure. A steelworks E.O.T. crane structure is, however, essentially part of a machine and as such is subjected to frequently varying loads. Few complete failures in members due to fatigue have been experienced, as rivet loosening takes place, transferring the load away from the overstressed joints before complete failure occurs. Undesirable racking of the structure then arises and considerable maintenance work may have to be carried out. Rivet loosening is in fact a form of fatigue failure, although it is not generally recognized

as such. At present, as indicated earlier, the stress level in cranes is generally not high but there is pressure from the steel industry for lighter crane structures or, alternatively, higher loadings on existing crane structures, with the result that higher stresses have to be contemplated.

There is little doubt that under these circumstances some more satisfactory method must be found of dealing with dynamic stresses than the old method of a ' safety factor ' on an assumed safe static stress. To allow further discussion of the different aspects relating to the fixing of permissible stresses in crane structures, the following points will be considered.

Ranges of stress observed in crane structures
Relevant data from laboratory fatigue tests
Clauses in current specifications.

Observed Stress Ranges

The allowable maximum stress in a material subject to stress fluctuations is dependent on the amplitude of the stress range, and therefore on the minimum as well as the maximum loading condition. This requirement is one of the points of difference between design for fluctuating loadings and design for static loadings only. Stress reversals are most likely to occur in lattice truss structures, because the movement of the load reverses the direction of the shear forces, and hence the stresses in the central diagonal bracing members. In bottom chord members the extent of the stress variation is limited by the magnitude of the crab end-approach, but in top chord members local wheel-loading effects may in some cases cause reversal of fibre stresses. Table X shows the stresses occurring in various members of two of the lattice-type cranes tested. The stresses shown are due to dead loading and the loaded or unloaded crab at appropriate positions across the crane bridge. No dynamic effects are included.

The ratios of minimum to maximum stresses given in column 8, Table X, show that stress reversals occurred as expected in the top booms, due to local bending, and in the centre bay diagonals, due to shear reversal. The stress ranges are 3·3–6·4 tons/in^2 in these members. For the other members the stresses do not appreciably reverse and the ranges of stress were about 1·5–3·5 tons/in^2. These results show that even without including definite dynamic or shock effects appreciable stress variations may occur in existing lattice-type cranes.

Laboratory Fatigue Tests

A very large part of the published literature on fatigue deals with results from laboratory tests using small polished specimens subjected to reversed bending stresses, and there is a more limited amount of information available dealing with the effect of notches on such specimens. Results from such tests are clearly not immediately applicable to fabricated structures such as E.O.T. crane bridges except to indicate, for example, the importance of avoiding stress concentrations as far as possible.

Some fairly extensive tests on mild- and alloy-steel riveted joints were reported by Wilson and Thomas[12] in 1938, and some recent work on the fatigue strengths of riveted and bolted connections was included in the 1954 Annual Report of the Association of American Railroads. In general, however, interest in the fatigue of large-scale riveted joints has been confined to the aircraft industry, where the demand for light structures operating under increasingly arduous conditions has led to numerous problems. As already noted, it is generally considered that at the present time there are no troubles arising in crane structures due to fatigue and, although this view may overlook some occasional loose rivets, it is no doubt largely true. Whether it will remain true in the future in structures subjected to increased loadings remains to be seen and there is need for further tests to be carried out to provide more complete data.

Reference may also be made to the strength of welded joints under conditions of varying stress, as welded construction is allowed by the B.I.S.R.A. Specification and has been adopted by some continental crane makers and at least one firm in the U.K. In general, welded structures may be considered more liable to serious fatigue failure owing to the stress concentrations at joints extending to the extreme fibres of the material where high bending stresses may already exist. Also, the resulting monolithic form facilitates the propagation of cracks throughout the structure unchecked by boundaries. The fatigue strength of welded joints has received more attention in laboratory tests than that of riveted joints, possibly owing to the more catastrophic failures that can occur with this form of fabrication. Numerous papers have been published and useful surveys have been made by Weck,[13, 14] to which reference may be made for further details. The recent publication of the Battelle Memorial Institute, "The Fatigue of Metals and Structures,"[15] also contains much useful information. Much more work, however, needs to be done to establish with greater certainty the maximum stresses permissible in large built-up structures operating under complex loading conditions.

Clauses in Current Specifications

In the last few years, numerous revisions of old Specifications have taken place and, following their usual policy, the British Standards Institution have endeavoured to introduce a degree of uniformity in clauses common to a number of allied Specifications. In dealing with crane structures, therefore, a general Specification for allowable stresses has been issued as B.S. 2573 : 1955 "Report on Permissible Stresses in Crane Structures" which was intended to be applied to all Specifications dealing with the structures of various types of crane (e.g. jib, derrick, E.O.T., etc.). For all these types the same basic stresses for tension, compression, and shear have been laid down and these in turn generally conform with the basic stresses previously laid down in B.S. 449 : 1948 "The Use of Structural Steel in Building." As the foreword to the report points out, the basic stresses recommended are generally higher than the working stresses permitted in the existing British Standard Crane Specifications, but the user of heavy-duty cranes is said to be safeguarded by the introduction of stress and impact factors not previously given.

The procedure in the report with regard to E.O.T. cranes is that all types are classified according to

the severity of duty, guided by the number of hours in service per year; five classes of respectively 0–1000, over 1000–2000, over 2000–3000, over 3000–4000, and above 4000 hours per year are used. Steelworks service and light process cranes are in the fourth class (Class 3) and steelworks continuous process, magnet, and grabbing duty cranes in the fifth class (Class 4). To obtain the actual working stresses, the basic stresses have to be multiplied by the stress factor S, introduced to make provision for the effect of fatigue under average conditions of working. In the classification, the value of S decreases as the number of hours of service per year increases, being 0·75 and 0·70 for the two classes of crane referred to above.

The stress factors have presumably been linked to the hours of service per year on the basis of the well established fact that under fatigue conditions the allowable range of stress decreases as the total number of applied stress cycles increases. In the preparation of the B.I.S.R.A. Specification it was, however, felt that the present lack of knowledge of the form of the fatigue-life/stress-range curve for fabricated structures, and the uncertainty about the numbers and magnitudes of the stress cycles occurring in normal crane working, made design for unlimited fatigue life more advisable. The B.I.S.R.A. Specification accordingly lays down the fatigue factors for different degrees of stress reversal based on an assumed value of 2 million stress cycles. It may be mentioned again that the fatigue factors adopted by B.I.S.R.A. follow those accepted by the B.S.I., in the April, 1955, draft revision of B.S. 153: Part 3*B*: "Girder Bridges (Steel)" and cover both riveted and welded construction. The B.I.S.R.A. Specification (1955) employs the same basic stresses for tension, compression, and bearing as B.S. 2573. The shear stresses differ slightly, being 6·5 tons/in^2 (B.I.S.R.A.) and 6·0 tons/in^2 (B.S. 2573).

There is clearly some difference in viewpoint between these two Specifications, and it may be pointed out that the B.I.S.R.A. Specification only requires stress factors as low as 0·75 and 0·70 (given by B.S. 2573 for Classes 3 and 4) when stress reversals of 25% and 50% take place in the members. Such marked stress variations in which the stress actually changes sign generally occur in only a few members of a crane structure (*see* Table X).

CONCLUSIONS

The basic requirement for the design of steelworks E.O.T. crane structures is that, at minimum cost, they should be adequately robust to withstand continuous heavy usage.

The tests carried out by B.I.S.R.A. in this investigation suggest that, even with this requirement considered, some cranes in operation are of heavier construction than is necessary for their duties.

Reasons for undue weight include:

(1) Inadequacies of some existing specifications
(2) Conservative design intended to ensure safety and continuous operation of the crane
(3) Use of insufficiently comprehensive design methods
(4) Extensive use of heavy plating for access and increased weight of modern mechanical and electrical equipment.

Close design without introducing risk may be achieved by use of:

(1) Appropriate dynamic load factors for particular cranes
(2) A design method that takes into account the auxiliary as well as the main girder structure and pays due regard to the points of application of vertical and lateral loads
(3) Permissible stresses dependent on the degree of stress fluctuation in individual members.

Values of the impact effects for a number of types of steelworks E.O.T. cranes and simplified design formulae have been given in this paper. Appropriate permissible stresses incorporating fatigue factors are given in the B.I.S.R.A. Specification for Heavy Duty E.O.T. Cranes in Steelworks (1955), the structural clauses of which have been based on the results of this investigation. As a general consideration it is suggested that the structure is best able to resist impact loadings if all members are as nearly as possible designed to the same stress level without waste of material. For economy, this stress level should be the maximum permissible when taking into account the stress fluctuations in the members.

Acknowledgments

The authors would like to express their very grateful thanks to all the steelworks managements who gave permission for the tests to be carried out and to the steelworks personnel who greatly facilitated the work. For much information concerning the cranes the authors are indebted to the various crane manufacturers. Thanks are also due to their colleagues in the Electrical Engineering Section of B.I.S.R.A., who gave valuable assistance in obtaining the stress records. The authors wish to record their appreciation of the encouragement given throughout the work by Mr. J. S. Terrington, Head of the Civil Engineering Section, B.I.S.R.A.

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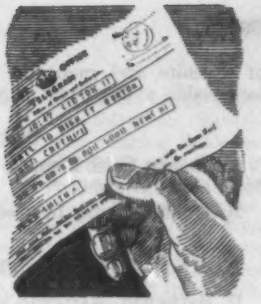
N E W S

Announcements and News of Science and Industry



THE IRON AND STEEL INSTITUTE

Medallists of 1958

The following awards have been made by the Council:
Bessemer Gold Medal for 1958: Mr. W. F. Cartwright (Steel Company of Wales Ltd).
Sir Robert Hadfield Medal for 1958: Mr. W. C. F. Hessenberg (B.I.S.R.A.)

Annual General Meeting, 1958

The 89th Annual General Meeting of The Iron and Steel Institute will be held at 4 Grosvenor Gardens, London, S.W.1, on Wednesday and Thursday, **7th and 8th May.** The programme of the meeting is as follows:

Wednesday, 7th May, 1958

2.45 to 3.45 p.m.	Formal Business, including: Presentation of Report of Council and Accounts for 1957; presentation of medals and awards; election of members.
3.45 to 4.45 p.m.	Induction of the new President, Mr. C. R. Wheeler, C.B.E. Presidential Address.
7.00 for 7.30 p.m.	Members' Dinner at Grosvenor House, Park Lane, London W.1.

Thursday, 8th May, 1958

10.0 to 11.30 a.m.	Joint discussion on: "Carbide Precipitation in Several Steels containing Chromium and Vanadium." By A. K. Seal and R. W. K. Honeycombe. (*January*, 1958). "The Effect of Tantalum and Niobium on the Tempering of Certain Vanadium and Molybdenum Steels." By A. K. Seal and R. W. K. Honeycombe. (*April*, 1958). "The Tempering of Low-alloy Creep-resistant Steel containing Chromium, Molybdenum, and Vanadium." By E. Smith and J. Nutting. (*December*, 1957).
11.45 to 1.0 p.m.	Joint discussion on: "Low-carbon Bainitic Steels." By K. J. Irvine and F. B. Pickering. (*December*, 1957). "The Metallography of Low-carbon Bainitic Steels." By K. J. Irvine and F. B. Pickering. (*February*, 1958).
2.30 to 3.15 p.m.	Discussion on: "Effect of Phosphorus on the Tensile and Notch-Impact Properties of High-purity Iron and Iron–Carbon Alloys." By B. E. Hopkins and H. R. Tipler. (*March*, 1958).
3.15 to 4.0 p.m.	Discussion on: "Variation of Transformation Characteristics within Samples of an Alloy Steel." By W. Steven and D. R. Thorneycroft. (*September*, 1957).

Special Meeting in Belgium and Luxembourg

The Institute is holding a Special Meeting in Belgium and Luxembourg from **18th to 28th June.** It will form part of the Journées Internationales de Sidérurgie, being organized by the Centre National de Recherches Métallurgiques, the Groupement des Hauts Fourneaux et Aciéries Belges, and the Groupement des Industries Sidérurgiques Luxembourgeoises. The general theme of the meeting will be "New Manufacturing Processes for Use in Iron and Steelmaking"; at the technical sessions, papers from Austria, Belgium, Canada, France, Germany, Italy, Luxembourg, Sweden, the U.K., and the U.S.A. are to be presented and discussed. The meeting will be divided into three sections, located at Liège, Luxembourg, and Charleroi and Brussels. A full programme of works visits and social functions has been arranged, in addition to the technical discussions, and there is also a ladies' programme.

The outline programme was published in the December, 1957, issue (p. 344); the full programme will appear shortly in the *Journal*.

NEWS OF MEMBERS

Dr. **B. G. Baldwin** has been appointed Assistant Chief Metallurgist of the Steel Division of the Steel Company of Wales Ltd.

Mr. **P. R. Belcher** has joined Vandervell Products Ltd.

Mr. **W. R. Beswick** has agreed to serve on the advisory council on Middle East trade set up by the Government.

Mr. **F. C. Braby** has been appointed a member and chairman of the Industrial Coal Consumers' Council.

Mr. **W. L. Cave** has been appointed to the Board of H. F. Spencer and Co., Ltd.

Mr. **I. Codd** has been awarded the degree of Ph.D. by the University of Leeds.

Mr. **E. F. Farrington** has been appointed Development Engineer at the Appleby-Frodingham Steel Company, with direct responsibility to the Chief Engineer.

Mr. **Edward J. Hanley** has been elected to the Board of the Westinghouse Air Brake Company.

Dr. **B. R. Nijhawan** has received the "Padma Shri" award from the President of the Union Republic of India in recognition of his exceptionally distinguished services in the fields of science in India.

Mr. **A. J. Peech** has been appointed a Director of Owen and Dyson Ltd.

Mr. **C. Pullan** is Chairman of the Roll Makers' Association.

Dr. **P. P. G. L. Siriwardene** has been appointed a Director of the Government-sponsored Ceylon Mineral Sands Corporation, set up to exploit the large deposits

of ilmenite and monazite in Ceylon. He retains his lectureship at the University of Ceylon, Colombo.

Obituary

Mr. **Robert Keith Fleming** (*elected* 1948), of Bedford, on 3rd February, 1958.

Mr. **John Anthony Lovelee** (*elected* 1946), of Kettering.

CONTRIBUTORS TO THE JOURNAL

D. Buchanan, B.SC.(ENG.)—Civil Engineering Section, Plant Engineering and Energy Division, British Iron and Steel Research Association.

David Buchanan was educated at the Royal Liberty Grammar School, Romford, Essex, and at Queen Mary College, London University, where he obtained a B.Sc. (Eng.) degree with first-class honours in 1945. From 1945 to 1947 he worked as a student apprentice with Vickers-Armstrong Ltd., at Newcastle-upon-Tyne and Chertsey, Surrey. He returned to London University in 1947 on the staff of the Mechanical Engineering Department of King's College, where he carried out research on methods of measuring particle sizes in fine powders. Mr. Buchanan joined B.I.S.R.A. in 1951; he has been engaged primarily on a programme of stress measurements on steelworks E.O.T. cranes. Other projects he has worked on have covered vibration isolation and works water systems.

A. K. Seal, B.SC., B.E.(MET.), PH.D.—Assistant Professor of Metallurgy, Bengal Engineering College, Howrah, India.

Arun Seal graduated from Calcutta University with honours in chemistry in 1947. He then entered the Bengal Engineering College, and graduated in metallurgy with first-class honours in 1951. For the next two years he worked as a graduate apprentice at the Indian Ordnance Factory, Ishapore, until he came to England in 1953 on a State scholarship. He was awarded the degree of Ph.D. in metallurgy by the University of Sheffield in 1956, and won the Brunton Medal and Award for his thesis.

R. G. Tyler, B.SC.(ENG.)—Lecturer, Aeronautical and Mechanical Design Department, Hatfield Technical College, Hertfordshire.

Mr. Tyler obtained the London University external degree of B.Sc.(Eng.) with second class honours at Brighton Technical College in 1946. He worked on the Power Plant Stress Office of the Bristol Aeroplane Company Ltd. until 1949, when he joined the Bridge Section of the West Sussex County Council Surveyor's Department. He left there in 1952 to join the Civil Engineering Section of the British Iron and Steel Research Association's Plant Engineering Division, where the work on cranes described in the paper in this issue of the *Journal* was carried out. Mr. Tyler took up his present post in 1956.

R. G. Ward, M.A., PH.D.—Lecturer in Metallurgy, University of Sheffield.

Robert George Ward was educated at Ipswich School; after serving a technical apprenticeship at the R.A.E., Farnborough, he became a Scholar of Christ's College, Cambridge. He obtained a B.A. in Natural Sciences in 1951, and a Ph.D. in 1954, for work on the extraction and purification of copper, under Dr. T. P. Hoar. He then went to Sheffield University as J. H. Andrew Research Fellow to study the fracture of cast steel, and was appointed Lecturer in Metallurgy in 1956. Dr. Ward's research interests include brittle fracture, slag–metal interactions, and the nature of the liquid state.

IRON AND STEEL ENGINEERS GROUP

Thirty-sixth Meeting

The Thirty-sixth Meeting of the Iron and Steel Engineers Group will be held at the Institution of Electrical Engineers, Savoy Place, London W.C.2, on Wednesday and Thursday, **16th and 17th April,** from 10 A.M. to 4 P.M. each day.

The first day will be devoted to the discussion of a paper on "Modern Developments of the Ward-Leonard Principle and Applications in Steelworks," by G. Ovens and C. A. Dodd (McLellan and Partners), in the morning and to a general discussion of "Electrical Maintenance in Iron and Steel Works" in the afternoon.

The second day will be devoted to the discussion of papers from B.I.S.R.A. on "The Application of Remote Position Control to Screwdown Drives of Rolling Mills" by L. N. Bramley, G. K. Steel, and F. Seredynski, and "The Application of Remote Position Control to Forging" by F. Seredynski, G. K. Steel, and others, in the morning, and "Translator Control" by W. N. Jenkins in the afternoon.

BRITISH NUCLEAR ENERGY CONFERENCE

Forthcoming Meeting

The Institute of Metals is sponsoring a half-day symposium on "Plutonium and Methods of Handling It," to be held at Church House, Great Smith Street, London, S.W.1, at 2.30 P.M. on Thursday, **1st May.**

The following papers, all of which are to be printed before the meeting in the *Journal of The Institute of Metals*, are to be presented and discussed:

"A history of the early British work on plutonium," *by J. G. Ball and W. B. H. Lord.*

"Some facilities for the study of plutonium and its alloys," *by G. K. Williamson, D. M. Poole, and J. A. C. Marples.*

"Techniques for the study of plutonium metal," *by W. B. H. Lord and M. B. Waldron*

"The plutonium–iron system," *by P. G. Mardon, H. R. Haines, J. H. Pearce, and M. B. Waldron.*

"A preliminary investigation of the plutonium–thorium system," *by D. M. Poole, G. K. Williamson, and J. A. C. Marples.*

"Some investigations on plutonium metal," *by E. Dempsey and A. E. Kay.*

Members are also invited to attend the Institute's meeting at 10 A.M. that day on "The life of fuel elements," also being held at Church House.

SOCIÉTÉ FRANÇAISE DE MÉTALLURGIE

At the Annual General Meeting of the Société Française de Métallurgie, held in Paris on 10th February, 1958, Monsieur Jacques Pomey was succeeded as President by Monsieur P. M. Epron, Managing Director of the Société Lorraine-Escaut.

BRITISH IRON AND STEEL RESEARCH ASSOCIATION

Conference on "Computers in the Steel Industry"

The Operational Research Department is arranging a one-day Conference on the use of digital computers in the iron and steel industry, on Tuesday, 15th April, 1958, at the Institute of Mechanical Engineers, Birdcage Walk, London, S.W.1. The Conference is intended mainly to provide senior executives from both the production and the administration sides of the industry with information on the possibilities of using computers within their companies. For those unfamiliar with the principles of these machines, demonstrations of the Pegasus computer now installed at B.I.S.R.A. will be given on the afternoon of Monday, April 14th, and on the morning of Wednesday, April 16th.

NEWS OF SCIENCE AND INDUSTRY

Exhibition of Photomicrography

The Royal Microscopical Society is holding an exhibition of photography with the microscope, "Micro 58," at the Polytechnic, Regent Street, London W.1, from 23rd to 30th July. An invitation is extended to all photomicrographic workers, especially in the metallurgical fields, to submit series of micrographs, a coherent resumé of a study of a particular problem, or related research exhibits. A printed programme is being published, and the title, authorship, and a 50-word abstract of the exhibit should be submitted to R. Setterington, Esq., Hon. Secretary, Micro 58, Royal Microscopical Society, Tavistock House South, London W.C.1, before April 30th. Exhibits can be accepted up to 20th June. All exhibits, apart from coloured transparencies, should be mounted on white card 20 in. × 16 in.; this area may include one or more pictures with a suitable caption.

Safety in the Iron and Steel Industry

The first issue of "Safety," a new magazine being published by the Accident Prevention Committee of The British Iron and Steel Federation, appeared recently. It will be published in future three times a year. 20,000 copies of the first issue have been printed, to allow for one copy to be available for every fifteen persons employed in the industry; the magazine is being circulated to managers, foremen, safety officers, trade union officials, and members of joint safety committees.

"Safety" will contain pictorial articles, reports and reviews, correspondence, and information on a wide variety of subjects connected with accident prevention and public health. The first issue is concerned chiefly with aspects of safety in the iron and steel industry, both in the United Kingdom and abroad; future issues will contain articles on safety in other industries and in the home.

Investment Casters Meeting

The 1958 meeting of the European Investment Casters' Association is being held in Paris from 18th to 21st May. Full details may be obtained from P. Chevé, c/o Compagnie des Ateliers et Forges de la Loire, 12 rue de la Rochefoucauld, Paris 9e.

Changes at N.P.L.

Following a comprehensive review of the organization and programmes of work of the National Physical Laboratory carried out in 1957, the existing Divisions of Electricity, Metrology, and Physics and the Test House are being replaced by three new Divisions, to be called Standards, Applied Physics, and Basic Physics.

The Standards Division will be responsible for work on standards of length, mass and time, of electrical and magnetic quantities and temperature. The Applied Physics Division will be responsible for work in the field of classical physics of immediate value to industry (excluding optics); the principal areas covered will be electrotechnics, acoustics, heat, and radiology. The Basic Physics Division will be pioneering developments in branches of non-nuclear physics which have potential industrial applications in the less immediate future.

Indian Blast-furnace Plant

The first of two blast-furnaces built by Ashmore, Benson and Pease and Co., for the Indian Iron and Steel Company Ltd. was blown-in in January, two months ahead of schedule. This furnace, which is the largest so far in operation in India, has a rated capacity of 1200 tons of iron a day. The second furnace is planned to go into operation in the autumn of this year.

Tonnage Oxygen Company

The British Oxygen Group has formed a new company, Tonnox Construction Ltd., in order to simplify administration, particularly in connection with the organization of tonnage oxygen plant for steelworks.

New Vacuum Melting Plant

William Jessop and Sons Ltd., have ordered a consumable electrode arc-melting furnace from W. C. Heraeus of Hanau, Western Germany. The new furnace will be the largest of its kind in Europe and will be used for the production of "Vacumelt" steel and "Hylite" titanium alloys; it is hoped that its use will treble the Company's present production capacity. It will be capable of producing ingots up to 24 in. dia. and a weight of 7000 lb; full automatic control and safety equipment are incorporated in the new plant. The furnace was ordered through the German company's U.K. agents, Fleischmann (London) Limited.

Metals and Alloys above 1200° C

A Symposium on "The Study of Metals and Alloys above 1200° C" is to be held at Oxford on 17th and 18th September. The meeting will consist of two morning and two afternoon sessions, beginning at 10 A.M. on Wednesday, 17th September and ending at 5 P.M. on Thursday, 18th September. Arrangements have been made for accommodation at St. Edmund Hall. The Symposium will deal with a wide range of subjects, including the preparation of metals and alloys of high melting point, the investigation of crystal structure and of phase equilibrium, the measurement of physical and mechanical properties, and the problem of refractories. Enquiries from those interested should be sent to Professor W. Hume-Rothery, O.B.E., F.R.S., Department of Metallurgy, University Museum, Oxford.

DIARY

1st Apr.—INSTITUTE OF METALS (Oxford Local Section)—Annual General Meeting—Department of Metallurgy, University Museum, Parks Road, Oxford, 7 P.M.

1st Apr.—INSTITUTION OF ENGINEERS AND SHIPBUILDERS IN SCOTLAND—"Provision of Ore Handling Facilities at General Terminus Quay, Glasgow," by A. Young and G. Gray—39 Elmbank Crescent, Glasgow, 6.30 P.M.

3rd Apr.—INSTITUTE OF METALS (Local Section)—Annual General Meeting, followed by "New Protective Coatings for Metals," by W. E. Ballard—17 Belgrave Square, London, S.W.1, 6.30 P.M.

10th Apr.—EAST MIDLANDS METALLURGICAL SOCIETY—Annual General Meeting, followed by "Continuous Rolling of Stainless Steel Strip," by J. A. Campbell—Nottingham and District Technical College, Shakespeare Street, Nottingham, 7.30 P.M.

10th Apr.—LEEDS METALLURGICAL SOCIETY—"Pressure Die Casting," by G. Kelly—West Yorkshire Foundries, 7.15 P.M.

11th Apr.—LINCOLNSHIRE IRON AND STEEL INSTITUTE—Annual Dinner.

11th Apr.—WEST OF SCOTLAND IRON AND STEEL INSTITUTE—"From Furnace to Mould—a Symposium": papers by T. McCulloch, T. Urie, and R. McDonald—39 Elmbank Crescent, Glasgow, 6.45 P.M.

14th Apr.—CLEVELAND INSTITUTION OF ENGINEERS—"Starting from Scratch: the Construction and Operation of Ravenscraig Works," by R. P. Towndrow—Cleveland Scientific and Technical Institution, Middlesbrough, 6.30 P.M.

14th Apr.—INSTITUTE OF WELDING (Sheffield and District Branch)—Annual General Meeting—Grand Hotel, Sheffield, 7.15 P.M.

14th–18th Apr.—AMERICAN WELDING SOCIETY—Annual National Meeting and Welding Show—St. Louis, Mo., U.S.A.

15th Apr.—BRITISH IRON AND STEEL RESEARCH ASSOCIATION—Conference on the Use of Digital Computers in the Iron and Steel Industry.

15th Apr.—NEWPORT AND DISTRICT METALLURGICAL SOCIETY—Annual Meeting—Whitehead Institute, Cardiff Road, Newport, 7 P.M.

15th–17th Apr.—INSTITUTE OF FUEL—Residential Course on "Science in the Use of Coal"—Sheffield University.

16th Apr.—BRITISH NUCLEAR ENERGY CONFERENCE—"Operational Experience—Calder Hall," by K. L. Stretch—Institution of Electrical Engineers, Savoy Place, London W.C.2, 5.30 P.M.

16th Apr.—SOCIETY OF CHEMICAL INDUSTRY (Corrosion Group)—Annual General Meeting and Spring Lecture: "Corrosion Research and Its Industrial Background," by Dr. W. H. J. Vernon—14 Belgrave Square, London, S.W.1, 6.30 P.M.

16th–17th Apr.—THE IRON STEEL INSTITUTE (Iron and Steel Engineers Group)—Thirty-sixth Meeting—Institution of Electrical Engineers, Savoy Place, London, W.C.2.

21st Apr.—SHEFFIELD SOCIETY OF ENGINEERS AND METALLURGISTS—Film night—Engineering Lecture Theatre, University Buildings, St. George's Square, Sheffield, 7.30 P.M.

21st–23rd Apr.—METAL POWDER ASSOCIATION—14th Annual Meeting—Philadelphia, Pa., U.S.A.

23rd Apr.—INSTITUTE OF BRITISH FOUNDRYMEN (London Branch)—Annual General Meeting—Constitutional Club, Northumberland Avenue, London, W.C.2, 7 P.M.

28th Apr.—INSTITUTE OF BRITISH FOUNDRYMEN (Sheffield and District Branch)—Annual General Meeting, followed by "Mould Drying," by W. J. Colton—Grand Hotel, Sheffield, 7 P.M.

28th Apr.–2nd May—INSTITUTE OF METALS—Golden Jubilee Meeting—Church House, Westminster, London, S.W.1.

29th Apr.—NORTH-EAST METALLURGICAL SOCIETY—Annual General Meeting—Cleveland Scientific and Technical Institution, Middlesbrough, 7.15 P.M.

1st May—BRITISH NUCLEAR ENERGY CONFERENCE—Symposium on "Plutonium and Methods of Handling It"—Church House, Great Smith Street, London, S.W.1. 2.30 P.M.

1st May—INSTITUTE OF METALS—Jubilee Banquet—Grosvenor House, Park Lane, London, W.1.

1st May—LEEDS METALLURGICAL SOCIETY—"Chromising," by Dr. M. L. Becker (preceded by Annual General Meeting)—Chemistry Wing, The University, Leeds. 7.30 P.M.

5th–8th May—NATIONAL WELDING SUPPLY ASSOCIATION—Annual Meeting, Miami Beach, Fla., U.S.A.

CO-OPERATIVE TRANSLATION SERVICE

The following translations are now available, in addition to those given on p. 280 of the March, 1958, issue of the Journal:

590. GONCHAROV *et al.*: "Phosphate and Water-glass Coatings in Wire Prior to Drawing." *Stal*, 1957, May, pp. 464–465. (£1 15*s.* 0*d.*)

601. LEDER: "Descaling in Hot Rolling." *Stahl u. Eisen*, 1957, May 2nd, pp. 591–593. (£2 10*s.* 0*d.*)

616. BAAKE and STOLLBERG: "Results of New Studies made with O.H. Furnaces, and particularly with those of the Maertz type." *Neue Hütte*, 1957, Feb./Mar., pp. 157–168. (£7)

733. HAMMER *et al.*: "The Mechanism of Top Blowing." *Stahl u. Eisen*, 1957, Sept. 19th, pp. 1303–1308. (£2 15*s.* 0*d.*)

734. HULTGREN *et al.*: "Isothermal Transformation of Austenite." *Jernkontorets Ann.*, 1951, vol. 135, pp. 403–494. (£10 0*s.* 0*d.*, text only. The 105 illustrations can be supplied for an additional £3 10*s.* 0*d.*)

737. NASE: "Dust Removal in a Pallet Sintering Plant." *Stahl u. Eisen*, 1957, Aug. 8th, pp. 1070–1074. (£2 15*s.* 0*d.*)

753. SIMON: "The Bar Iron Rolling Mill of the Sidelor Plant at Homécourt." *Tech. Mod.*, 1957, July, pp. 70–72. (£2)

754. ROYER: "The 700 mm. Rail Mill of the Micheville Works of l'Union Sidérurgique Lorraine." *Tech. Mod.*, 1957, July, pp. 73–77. (£3 10*s.* 0*d.*)

756. MALLET: "The Montataire Works of Usinor. Continuous Pickling Line—New Four Stand Mill—Annealing Plant—Skin Pass Mill." *Tech. Mod.*, 1957, July, pp. 87–93. (£4 10*s.* 0*d.*)

757. BLAIN: "Preset Reduction Skin-pass Mill." *Tech. Mod.*, 1957, July, pp. 103–104. (£2)

758. JOBARD: "Four-high Cold Reversing Mill, Annealing Plant and Two-high Skin Pass Mill of the S.A.F.E." *Tech. Mod.*, 1957, July, pp. 108–110. (£2 15*s.* 0*d.*)

759. FRIRY: "The New Plate Plant at the Longwy Works of Lorraine-Escaut." *Tech. Mod.*, 1957, July, pp. 114–118. (£3 10*s.* 0*d.*).

776. TRENTINI and ALLARD: "Refining of Phosphoric Iron, and especially Basic Bessemer Iron, with Pure Oxygen by the IRSID Process." *Centre Doc. Sidér., Circ. Inform. Tech.*, 1957, vol. 14, pp. 2259–2266. (£1 10*s.* 0*d.*)

787. ZBOROVSKII *et al.*: "Hydrodynamics of (Proof of Convection in) Liquid Steel in Ingot Moulds." *Stal*, 1957, Jan., pp. 24–30. (£4 10*s.* 0*d.*)

788. WEVER *et al.*: "Supervision and Control of the Basic Bessemer Process by Evaluation of the Temperature Radiation of the Bath and the Spectrum of the Converter Flame." *Stahl u. Eisen*, 1955, May 5th, pp. 549–559. (£6 5*s.* 0*d.*)

792. WENGLER and AUSEL: "Application of Complexometric Analysis in a Steelworks Laboratory." *Arch. Eisenhüttenwesen*, 1957, Jan., pp. 7–12. (£4)

797. KRÄCHTER and JÄGER: "Quantitative Determination of Alloy Elements in Steel by X-ray Fluorescent Spectroanalysis." *Arch. Eisenhüttenwesen*, 1957, Oct., pp. 633–639. (£3 15*s.* 0*d.*)

802. DUBININ: "Diffusion of Niobium into Steel from the Gas Phase." *Zhur. Tekhn. Fiziki*, 1952, vol. 22, pp. 1730–1740. (£3 10*s.* 0*d*)

804. NEUMANN: "Application of the Cold Pilger Process and Comparison with Cold Drawing." *Z. Metallkunde*, 1957, Oct., pp. 564–568 (£3)

806. BÄRTSCHINGER: "Nodular Graphite in Cast Iron." *Schweizer Archiv*, 1949, March, pp. 75–84. (£5 10*s.* 0*d.*)

811. HEIMERL: "Continuous Pusher-type Heating Furnace with fully Automatic Control." *Stahl u. Eisen*, 1957, Dec. 26th, pp. 1873–1877. (£2 15*s.* 0*d.*)

812. KRÜGER and SCHMIDTMANN: "Effect of the Hydrogen Content on the Mechanical Properties of Converter Steels blown with Oxygen and Steam." *Stahl u. Eisen*, 1957, Dec. 26th, pp. 1868–1873. (£4 10*s.* 0*d.*)

820. KALLING and JOHANSSON: "Refining with Oxygen in the Rotary Furnace according to the Kaldo Process." *Stahl u. Eisen*, 1957, Dec. 26th, pp. 1885–1887. (This paper supplements the report published in *Stahl u. Eisen*, 1957, pp. 1308–1315, and includes discussion.) (£3)

822. MANNESMANNROHRE für das ÖLFELD: "Calculations of Crude Oil and Petrol Pipelines, and Calculation of Long-distance Gas-mains." Mannesmannröhren-Werke. (£3 15*s.* 0*d.*)

823. SPEITH *et al.*: "Desulphurisation in the Basic Open-hearth Process." *Stahl u. Eisen*, 1958, Jan. 9th, pp. 27–34. (£5 10*s.* 0*d.*)

834. KNÜPPEL *et al.*: "Temperature Measurement in the Basic Bessemer during the Blow." *Stahl u. Eisen*, 1956, Nov. 1st, pp. 1410–1416. (£5 10*s.* 0*d.*)

859. YUDOVITCH: "Use of Protective Coatings (of Waterglass) for decreasing Steel Decarburization." *Stal*, 1957, Jan., pp. 69–71. (£2)

862. NECHAEV: "Gas Turbines as Direct Sources of Blast-Furnace Blast." *Stal*, 1957, Dec., pp. 1140–1141. (£1 10*s.* 0*d.*)

867. GATTIKER: "The Shell Oil Gasification Process and its Application to Industry." *Erdöl u. Köhle*, 1957, vol. 10, pp. 581–584. (Summary). (£1 5*s.* 0*d.*)

868. PFLAUME: "New Developments in Furnace Construction for Drop Forgings." *Fertigungstechnik*, 1957, vol. 7, Feb., pp. 63–64. (£1 10*s.* 0*d.*)

869. KLEIN and WEGNER: "Modern Ideas on Track Laying using J-Flex and T-Flex Spring Spikes." *Eisenbahntechnische Rundschau*, 1957, No. 7, pp. 266–273. (£4 10*s.* 0*d.*)

870. LASHKO: "Equilibrium Diagram of Nickel-Silicon." *Dok. Akad. Nauk S.S.S.R.*, 1951, vol. 81, No. 4, pp. 605–607. (£1 5*s.* 0*d.*)

872. FIGEL'MAN and SHREIDER: "A Method of Studying Hydrogen Embrittlement of Steel." *Zavod. Lab.*, 1956, vol. 22, May, pp. 586–588. (£1 5*s.* 0*d.*)

Note:—When two copies are required, there will be 50% reduction for the second copy. Six copies can be bought for the price of two, and twelve copies for the price of three.

ABSTRACTS OF CURRENT LITERATURE AND BOOK NOTICES

Iron and Steel Manufacture and Related Subjects

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MINERAL RESOURCES

Geological Survey of the Utö Iron Ore Deposit to the South of Stockholm. H. Pilava-Podgurski. (*Sver. Geol. Unders. Årsbok.*, 1955, **49**, (541), Ser. C, pp. 54). Diamond drill exploration is reported and the origin of the deposit discussed.

A Geological Explanation of the Weakness in the Bed Rock of the Iron Mines of Central Sweden. N. H. Magnusson. (*Jernkont. Ann.*, 1957, **141**, (10), 601–632). The history of the ores and their formation and subsequent geological modifications are outlined and studies of strength and elasticity are reported. Practical consequences are discussed.

Colonial Geological Surveys. 1947–56. F. Dixey. (*Colonial Geol. Min. Res., Bull. Supp. No.* 2, 1957, pp. 129). Iron ore deposits are indexed.

BLAST-FURNACE PRACTICE AND PRODUCTION OF PIG IRON

Studies of the Permeability of Blast-furnace Burden Materials. J. M. Ridgion. (*J.I.S.I.*, 1958, Apr., **188**, 317–320). [This issue].

PRODUCTION OF STEEL

High-Grade Steel Production in the U.S.S.R. A. S. Nikolaev. (*Stal'*, 1957, (11), 987–991). A review.

The Smelting of Converter Steel with Top Oxygen Blowing. S. S. Afanas'ev, M. M. Shumov, Z. D. Epshtein, T. V. Andreev, N. I. Beda, I. I. Korobov, O. N. Kostenetsky, S. I. Lifshits, P. S. Rubinsky and S. N. Filipov. (*Stal'*, 1957, (8), 693–700). Soft rimming steel differing little from O.H. steel of the same quality was produced. No control difficulties were encountered and converter life was 200 heats after increasing the specific volume and improving the quality of periclase–spinel brick. Blowing time is decreased by increasing O_2 feed without increasing losses due to spattering and a yield of 88% was achieved. Plant using 10-t and 14-t converters is described with details of lining wear and of the water-cooled O_2 feed pipe. Raw material consumption is given.

Recent Trends in the Converter Process and the Possibility of their Domestic Introduction. V. Zsák. (*Kohászati Lapok*, 1955, **10**, Nov., 490–495). A critical review is given of the development of the converter process especially of pig iron, refractories and oxygen blowing.—P. K.

Refining of Stahleisen by the Oxygen–Steam Method. H. Neuhaus. (*Stahl u. Eisen*, 1957, 77, June 13, 816–818). The author reports the results of trials conducted at Haspe in 1955 of blowing stahleisen in conventional converters with O_2–steam mixtures. The ratio of O_2 to steam varied from 42 : 58 to 56 : 44% according to the amount of scrap charged and of Si present. The author compares the O_2–steam method with the LD (O_2 top blowing) method and found *inter alia*: Both processes yield high-quality steels with low P and N contents. The P level of the charge is not restricted and no brown waste gases were observed in the O_2–steam process, and the output in this process is 30% higher than in the LD process.—T. G.

Planning the Control of Production and Despatch in Open Hearth Shops. I. E. Moshkevich and Kh. P. Zaitsev. (*Stal'*, 1957, (8), 749–753).

The Terni Design of Open-Hearth Furnace. A. Rossin. ("*La Documentation Métallurgique*," 1956, July, No. 2 Special Sa. 2, 193–203, *IRSID reprint*). After considering results obtained in 1930 with the Terni design of ports on O.H. furnaces in Italy and England a trial of Terni ports was made on a 50-ton producer gas fired furnace at a French steelworks. The output rate increased by 22% to 8 t/h and the refractories consumption decreased by 40%. The design was adopted for the remainder of the melting shop with similar results. The design is described and also a water-cooling arrangement for the port not normally part of the Terni design. Reasons for this good performance obtained over 20 years ago are advanced and the question is raised whether a better performance has been obtained with oil firing.

Study on Scale Models of the Aerodynamics of the Open-Hearth Furnace. F. Husson, R. Durand and G. Cohen de Lara. (*La Documentation Métallurgique*, 1956, July, Special Sa. 2, 204–227, *IRSID reprint*). Studies on scale models of O.H. furnaces using air to represent the gas and warm air to represent the combustion air are described. Flow patterns and velocities are determined for a typical design of gas-fired O.H. furnace and for a Terni design with and without modifications, for various angles between the gas and air ports. It is concluded that the preliminary results obtained are insufficient to allow generalizations on the functioning of O.H. furnaces. The lines of future studies are given.

Heat Over Checkers Speeds Light-Up. (*Steel*, 1957, **141**, Aug. 19, 158–161). A method of warming up a cold O.H. furnace, which reduced the time before the first heat by 6 to 12 h is described. 4 gas burners were set through the checker chamber wall just above the top of the checker brick, and the burnt gas was draughted out of the centre furnace door. The progress of such an operation is described.—D. L. C. F.

Experiences of Putting a 125 t Open Hearth Furnace in Service at Stalinváros in Hungary. G. Répási. (*Kohászati*

Lapok, 1955, **10**, Aug., 337–349). The author describes the construction, heating system and steelmaking technology of a 125 t all-basic lined O.H. furnace at Stalinváros. He comments on the difficulties of steelmak ingfrom more than 70% hot charge, especially a high heat requirement, low yield of metal, large quantity of slag and longer time of finishing. Carburetted top gas was unsuitable for heating the furnace.

Russian Experiences of Rapid Steel Melting in Open Hearth Furnaces. (*Kohászati Lapok*, 1953, **8**, April, 81–85). The main principles of rapid steel melting in Russian O.H. furnaces, such as the best heating and charging methods and the most advantageous slagging practice are reported.—P. K.

The Rate of Heating of Open Hearth Furnaces. B. Selmeizi. (*Kohászati Lapok*, 1954, **9**, Jan., 2–9). The rate of heating up O.H. furnaces depends on the following factors: (1) Properties of the refractories, especially their thermal expansivity. (2) Extent of the brick lining. (3) Technology of the brick lining. (4) Urgency of the furnace output. The heating up period can be divided into three parts: (1) desiccation, (2) preheating and (3) heating at the operating temperature. The author gives a comprehensive review, mostly based on Hungarian and Russian experience, of the times necessary for these operations with the following results for furnaces with silica roofs: Heating to 150° C 5–10° C/hour, 150–300° C 10–20° C/hour, 300–650° C 20–40° C/hour, above 650° C 40–50° C/hour. For slow trans-formation of α- to γ-crystobalite in silica bricks, holding at 250° C for 3–7 hours is suggested.—P. K.

Experience in the Use of Sinter in Open Hearth Furnaces. N. A. Vecher, A. A. Lebedev, and N. D. Korneev. (*Stal'*, 1956, (12), 1080–1083). [In Russian]. The partial replacement of ore by sinter in 140-, 260- and 380-t silica and basic-roofed O.H. furnaces making rail and tube steels is described. This was found to result in a shorter melting period, with more fluid slags and better dephosphorization. The consumption of sinter exceeded that of ore by 13% on the average. No deleterious effects on the walls were observed and consumption of fettling materials remained unchanged, as did metal quality. No process complications occurred and the experience demonstrated that fine low-silica magnetite concentrates after sintering can advantageously replace ores.—S. K.

Rise in the Temperature of the Open-Hearth Bath during Blowing with Compressed Air. M. Ya. Medzhibozhskiĭ and I. A. Sokolov. (*Stal'*, 1957, (3), 220–227). [In Russian]. After a detailed theoretical consideration of chemical and thermal effects produced in the O.H. bath by blowing with air, experimental measurements, with immersion thermocouples, of metal temperature before and after air blowing in 190- and 30-tonne furnaces are described. The air blowing was found to accelerate temperature rises. This is due to the fact that carbon is oxidized mainly by hot O_2 from the furnace atmosphere. With 12–15 m³/min of air at 3·5–4·0 atm. (gauge) the metal temperature rose at about 3° C/min. The results obtained agree with calculations.—S. K.

The Economy of Using Oxygen in the Open Hearth Process. A. Vajk and Z. Csomós. (*Kohászati Lapok*, 1954, **9**, Apr., 151–154). According to a recent Russian publication the four main factors in the use of oxygen in the O.H. process are as follows: (1) Increase in output. (2) Saving of fuel and oxidizing ore. (3) Price and specific consumption of oxygen. (4) Decrease in life of the furnace lining. A balance sheet is drawn between these factors.—P. K.

Intensifying the Open Hearth Process by Means of Direct Oxidation. O. J. Jacunszkaia and M. N. Sztarovics. (*Kohászati Lapok*, 1953, **8**, Sept., 194–207, Oct., 212–223). Direct oxidation is most efficient for producing steel with < 0·1% C or using a hot charge in the O.H. furnace, and melting scrap with high Cr in the electric arc furnace. The use of oxygen lances is preferable to oxygen jets for faster refining, less smoke and less splash of slag. The life of oxygen lances depends on their dia. and increases with higher quantity and pressure of blown O_2. The best durability has been obtained by blowing 1300–1500 m³ O_2/h at 7–9 at. pressure through ¾–1 in. dia. lances immersed to the slag-metal interface. Experiments with pressurized air and air with 44–90% O_2 as well as 100% O_2 have shown that the rate of oxidation increases with higher O_2 content up to 90% O_2. More O_2 gives no further advantage. Compressed air can be satisfactorily blown into a bath with > 0·6% C, but min. 90% O_2 is necessary for blowing into a bath with < 0·25% C. Essentially more O_2 is needed for oxidizing 0·01% C per t of molten steel with < 0·1% C, than for oxidizing the same C rate in a bath with more C. In most cases an increase in output and an improvement of quality was observed by using direct oxidation in steel-making processes.—P. K.

The Use of Oxygen for Melting the Cold Charge in the Open Hearth Steelmaking Process. O. I. Jacunszkaja and M. N. Sztarovics. (*Kohászati Lapok*, 1953, **8**, Nov., 240–272). The blow of oxygen on the melting scrap is most effective when the temperature of the latter is about 1400° C. Using about 1 m³ O_2 at 5–7 at. pressure per t scrap for 10 min the time of experimental 180 t heats decreases by 25%, but simultaneously the repair time of the furnace increases by 42%.

Adoption of the Use of Oxygen for 370-ton Open Hearth Furnaces. I. A. Shmonin and A. P. Klyucherov. (*Stal'*, 1956, (12), 1076–1079). [In Russian]. The results of five months' use of oxygenated air in large O.H. furnaces are analysed. It is concluded that with an average O_2 content of 24·5% and O_2 consumption of 24·4 m³/t the hourly rate of production can be increased by 15·1% and the fuel burnt per t reduced by 17·5% compared with the best period of operating the magnesite–chromite furnaces without O_2. The tap-to-tap time showed a decrease of 1·72 hr. (14·6%). Maximal productivity (50 tons/hr) and minimal specific consumption of standard fuel (85 kg/t) was obtained on accelerating charging and heating by increasing thermal loads and O_2 consumption during these periods.—S. K.

Some Problems of Fining in Open Hearth Furnaces. V. Zsák. (*Kohászati Lapok*, 1952, **7**, Aug., 179–180). High C content and temperature of the molten steel increases the oxidation rate according to an equation given. A reduction of FeO in the steel is accompanied by an increase of Mn.—P. K.

The Physico-Chemical Reactions of Direct Oxidation in the Open Hearth Process. A. Vajk, Z. Csomos and L. Visnyovzsky. (*Kohászati Lapok*, 1953, **8**, Aug., 168–176). A comprehensive review is given of a Russian publication on the physico-chemical reactions of direct oxidation in the O.H. process. The temperature of the bath increases, the exothermic reactions are promoted, the order of the reactions changes i.e. the oxidation of C takes precedence and the oxidation of Mn and Cr slows down. Finally a reduction of Mn and Cr oxides takes place. By the use of 4·5–13 kg O_2 per t of steel, 20–30% of fuel can be saved and the output increased by 30%.—P. K.

Sulphur Exchange between Gaseous Phase and Bath in Basic Open Hearth Furnaces. S. N. Stupar'. (*Stal'*, 1957, (8), 707–713). Transfer of S from gaseous phase to bath occurs at the greatest rate during charging of the metallic portion of the burden. (17–25% per h as compared with 8–11% during heating up and 3–7½% during refining). The relationship between rate of absorption and rate of C elimination is linear. Transfer appears to occur mainly through the medium of "buttons" of metal ejected through the slag during boil. During the heat S is transferred from bath to gases at a fairly substantial rate carrying with it products of combustion. As the iron oxide content of slag is increased and the oxidizing atmosphere is enlarged removal of S increases, transfer to gaseous phase appears to occur by direct oxidation in the slag, the iron oxides providing a link in the process. To improve desulphurization a slag with basicity 3–3·5% and over 6% iron oxide must be made up and an oxidizing atmosphere maintained, this is best done by adding lime mixed with millscale.

The Role and Control of Slag in the Open Hearth Process. E. Szücs. (*Kohászati Lapok*, 1952, **7**, Sept., 209–214). The role and control of a suitable slag in the O.H. process are discussed comprehensively with examples. An explanation of slag foaming is given and proved experimentally.—P. K.

Regularity in the Changes of Hydrogen Content During Open Hearth Steelmaking. J. Verö. (*Kohászati Lapok*, 1954, **9**, Mar., 100–102). The author calculated from the experimental data of E. Piper *et al.* (*Stahl u. Eisen* 1953, **73**, 817) the changes of the theoretical hydrogen content in basic O.H. casts during the melting process. The calculation was based on the degassing effect of CO in the course of refining. He found that the difference between the real and theoretical hydrogen content increases with the melting time. This means that the molten steel dissolves hydrogen from the gas atmosphere with constant velocity.—P. K.

Life of Open Hearth Furnaces Using Oxygen in the Steelmaking Process. A. Vajk and Z. Csomós. (*Kohászati Lapok*,

1954, **9**, Jan. 20–21). According to a recent Russian publication the life of an O.H. furnace will be reduced by using an excessive quantity of oxygen to an extent up to 15% and the number of casts decreases to 120–200. The cause of this is the chemical attack of the smoke and of the splashed slag at the line of the furnace, especially at the roof of silica bricks. The life of all-basic lined furnaces is somewhat longer. Using 430–500 m^3 O_2/h is suggested in a 100–125 t O.H. furnace.

The Cooling Down of Industrial Furnaces, and in Particular of Open Hearth Furnaces. R. Schröter. (*Neue Hütte*, 1957, **2**, May, 285–289). Provided the difference in temperature is known between a layer that is already cooling down, and the layer that is not yet cooling down, the shortest permissible cooling period can be calculated, and cooling down of furnaces in practice can be controlled accordingly. It is shown that silica brickwork can be cooled down to 230° C at any practicable rate. Cooling by water sprays should be generally introduced. To increase the difference in pressure between furnace and flue, injection nozzles and fans should be used to pump in, and exhaust, air.—L. J. L.

Smoke Temperature at the Outlet from the Working Space of an Open Hearth Furnace. V. N. Kornfel'd, A. O. Voitov and V. I. Koshelev. (*Stal'*, 1957, (3), 213–219). [In Russian]. In the investigation described W–Mo thermocouples were regularly used to measure flue-gas temperature in the vertical channels and other points of 200-tonne O.H. basic-roofed furnaces. Over 60 heats were covered, including some with flame oxygenation to 25 and 30%. Results are plotted for various stages of the process and to show the effects of oxygenation. The temperature changes were found to reflect the dynamics of thermal processes occurring in the working space, and such measurements are proposed as impulses via a computer for the automatic control of firing rates and other factors.—S. K.

Control Problems in Metallurgical Furnaces. K. Loske. (*Silicates Indust.*, 1957, **22**, (5), 285–290). [In German]. Some of the practical problems arising in automatically controlled O.H. steelmaking are discussed.—P. F.

Control of Metallurgical Furnaces. K. Loske. (*Stahl u. Eisen*, 1957, **77**, June 13, 813–816). A review in a lecture of modern control techniques with particular emphasis on O.H. furnaces.—T. G.

Automatic Control of an Open-Hearth Furnace Burning Hot and Dirty Generator Gases. H. Stollberg. (*Neue Hütte*, 1957, **2**, Apr., 220–226). Difficulties of mechanization are listed. Control equipment is described. The construction of the gas control valve is explained in detail. Gas control and gas–air mixture control devices are discussed, and the economic and technical benefits of automation are extolled

Comparison of Different Methods of Atomisation of Oil in an Open-Hearth Furnace. G. Husson, A. Peters, R. Kissel and G. Jomier. ("*La Documentation Métallurgique*," 1956, July, No. Special Sa 2, 256–277, *IRSID reprint*). A comparison is made of the performances of a 45-t single uptake O.H. furnace for steam and air atomization of the oil. In addition to normal O.H. instrumentation, total radiation and suction pyrometers were installed for the measurement of flame radiation and combustion air temperature. The results, which are given in detail, showed that (1) the production rate increased strongly when the pressure of the atomizing air was increased from 5·5 to 8·7 Kg./cm^2 although flame radiation near the burner decreased by 7%; (2) the production rate did not change in a statistically significant manner when the atomizing agent was changed from air to steam though it tended to decrease; (3) oil consumption decreased when the pressure of the atomizing air was increased from 5·5 to 8·7 kg/cm^2; (4) oil consumption was slightly higher when atomizing with steam but the difference was not statistically significant; (5) the pig iron requirement of the charge increased on changing from air to steam; (6) the pig iron requirement did not change appreciably for a change in velocity at the burner; (7) the performance of the furnace was not changed appreciably by a change in the temperature of the atomizing air from 300° to 220° C.

Experience with the Crude Coal-Tar Firing of Open-Hearth Furnaces. W. Gerling and K. O. Zimmer. (*Stahl u. Eisen*, 1957, **77**, Aug. 8, 1075–1080). The design and operation of an 80-t O.H. furnace for firing crude coal tar are described. The tar flame is hotter than most of the other flames used in O.H. furnaces. This results in shortening of melting-down time, increase in refining rate and decrease of the sulphur content of the iron. A furnace fired with coal tar is particularly suited for the pig iron–ore process. Owing to the high temperature of the flame, roof life is only moderate, but the lining is not affected. The voluminous flue dust and the large quantities of ash made the re-design of the checkers necessary—T. G.

New Methods of Hot-Cooling. R. Vonnemann. (*Stahl u. Eisen*, 1957, **77**, Aug. 22, 1126–1135). The author describes a hot-cooling system based on steam-raising and natural convection flow of the water. This system has been applied to O.H. furnaces, blast furnaces and soaking pits as well as chimney stacks. The amount of fresh water used is materially reduced in this type of cooling and is only about 2% of the quantities used formerly.—T. G.

Possibilities of Utilizing the Heat Available on Cooling Open-Hearth Furnaces. R. Kremer. (*Hutník*, 1957, **7**, (5), 152–157). [In Czech]. Recent developments in the utilization of the heat acquired by the cooling water circulating around various parts of O.H. furnaces are surveyed and critically assessed. A cooling system in which the cooling elements are heat insulated, and in which superheated steam can be produced is considered to be desirable, as it can significantly increase the over-all thermal efficiency of the furnace. Such systems should be introduced rapidly into Czechoslovakia; some apparently are already being installed.—P. F.

Rapid Major Repair of a 260-ton Open-Hearth Furnace. A. A. Dubrovskiĭ, I. I. Lesunov and T. L. Levenskikh. (*Stal'*, 1956, (12), 1127–1130). [In Russian]. The organization and day-to-day conduct of the demolition and rebuilding of a 260-ton O.H. furnace which was completed in 13 days 13 hrs. are described. Bulldozers and excavators were used.—S. K.

Heat Exchange in Regenerators. J. Spal. (*Neue Hütte*, 1957 **2**, Apr., 234–245). Heat exchange in regeneration is considered as a stabilized periodic process. The case of a plate in a medium with sinusoidally variable temperature is discussed. Conclusions are drawn for any periodic temperature cycle. Heat exchange in the case of gas flow along the heating surface is examined.—L. J. L.

Development in Recuperator Design. G. Wellensiek. (*Giesserei*, 1957, **44**, Apr. 25, 245–247). The thermal conditions which have to be taken into account in the operation of recuperators are discussed. A new design of combined recuperator is described in which the radiation part and the convection part are combined in one unit. Thermal and operational advantages of this new design over conventional recuperator systems are described.—R. J. W.

On the Stability of Dinas Checkers in Open-Hearth Furnace Regenerators. I. A. Ol'khovskiĭ and A. P. Klyucherov. (*Stal'*, 1956, (12), 1072–1076). [In Russian]. In this article the reasons for the greater stability of silica checkers at Novo-Tagil' compared with that at Magnitogorsk are discussed. The O.H. furnaces at both plants are silica-roofed. Numerous samples of dust from the regenerators and samples of slag from the pockets were analysed. When refractoriness tests were made on various mixtures of dusts with the checker material lower values were obtained with the Magnitogorsk mixtures, and this is thought to be the main reason for the difference in checker life. The use of magnesite powder for fettling at Novo-Tagil' instead of dolomite powder is considered to be a contributory cause of comparatively long checker life.—S. K.

Investigations on the Refractory Linings, the Blowing Practice and the Size of Hot Blast Cupolas Used in Steel Plants. W. Patterson and A. F. Oberhofer. (*Giesserei*, 1957, **44**, Apr. 25, 227–237). The various parts of the furnace plant are described. The materials with which the furnace is charged are described and analyses given of the iron and the slag. A description of performance data of the plant includes items such as melting efficiency and the amount of blast used per kg carbon. Furnace height, cross-section at the tuyeres, heat balance of the plant, temperature measurements in the iron and slag and combustion ratios are all separately described.—R. J. W.

Experiments with a Stabilised Dolomite-lined Arc Furnace. A. Szerelmy. (*Kohászati Lapok*, 1955, **10**, Aug., 366–372). The author describes Rumanian experiments with a stabilised dolomite-lined 1 t Heroult furnace. The dimensions of the dolomite bricks are 18 × 12 × 6·5 cm. The construction of the furnace as well as the physical properties and the chemical and mineralogical composition of the bricks are given. The

roof was built from silica bricks. The comparatively short 78-charge life time was a result of the 1·5 t charges. Nevertheless it compares with the average 79 charge life time of the magnesite-lined furnace.—P. K.

Production of Structural Steel in Electric Furnaces with Oxygen Blowing. M. S. Gnuchev, V. P. Frantsov, G. F. Morenko, G. K. Komissarov and Z. V. Klochkova. (*Stal'*, 1957, (3), 228–232). [In Russian]. The melting of experimental heats of structural steels in electric furnaces characterized by the introduction of an increased quantity of lime during melt-down and the use of O_2 instead of ore during the oxidizing period is described. Neither metal quality nor furnace life was adversely affected.—S. K.

Removal of Small Amounts of Nitrogen from Molten Iron. W. P. Rees. (*J.I.S.I.*, 1958, Apr., **188,** 351). [This issue].

Non-Uniformity of Metal Heating in the Electric Arc Steel-Melting Furnace. V. M. Vinogradov. (*Stal'*, 1957, (3), 275–276). [In Russian]. In this article the non-uniformity of metal temperature in arc steel-melting furnaces and its effects on the determination of mean metal temperature are discussed and an investigation described. This was carried out on 5- and 15-ton furnaces and involved the measurement of metal temperature at various points in the bath and stages of the process and in the ladle with W–Mo immersion thermocouples: Mechanical stirring of the bath reduced but did not eliminate temperature gradients. Ladle measurements showed serious temperature variations from furnace to furnace at one works.—S. K.

Measures Taken in a Large Steelworks to Control the Load on the Electric Supply System. F. Hahne. (*Electrowärme*, 1957, **15,** May-June, 199–203). Control of a plant with 13 arc furnaces to keep within the maximum load specified is described.

Technical Guide to the Selection of Special Steels. G. Grenier. (*J. Four Electrique*, 1954, **63,** Nov.-Dec., 191–193; 1955, **64,** Jan.-Feb., 31–34, 38; Mar.-Apr., 71–75; May-June, 103–107; July-Aug., 131–134; Sept.-Oct., 174–177; Nov.-Dec., 201–203; 1956, **65,** Jan.-Feb., 31–35; Mar.-Apr., 63-65; May-June, 102-105; July-Aug., 133–136; Sept.-Oct., 177–180). In a series of articles the properties and uses of steels are considered in detail. The resistance of steel to stress and fatigue are explained. The allotropic forms of iron, the iron–carbon diagram and the microscopical examination of steels are described. The tempering of carbon steels and cementation and nitriding techniques are reviewed. The phase diagrams for special alloy steels are examined and the properties of stainless, high temperature and tool steels are considered.

Manufacture of Semi-killed Steel for Plate of Large Size. M. Mulsant. (*Centre. Doc. Sidér. Circ. Inform. Tech.*, 1957, (6), 1211–1225). The production of this type of steel at the Mont-Saint-Martin works of Lorraine-Escaut, France is described. The relative cost of making killed, semi-killed and rimming steels are considered in relation to the total cost of the final plate. Semi-killed steel is shown to have the lowest cost.—B. G. B.

Low Alloyed Structural Steels. M. P. Braun and P. J. Voronov. (*Kohászati Lapok*, 1952, **7,** Aug., 180–190). Russian heat treatment experiments with large Cr–Vi steel forgings, having a composition in range of C 0·36–0·40, Si 0·25–0·47, Mn 0·93–1·64, Cr 0·7–1·52, Ni 0·7–1·62, Mo 0·09% max. are described. The mechanical properties and fatigue limit of a steel containing C 0·39, Si 0·37–0·40, Mn 0·93, Cr 0·70, Ni 0·70, Mo 0·07–0·08% match those of steel of about C 0·39, Si 0·30, Mn 0·65, Cr 1·4 and Mo 0·25% content. Thus the former can replace the latter in large forged components for machines.—P. K.

The Rational Classification of Fine Constructional Steels. R. Calvo Rodes. (*Inst. Hierro Acero*, 1957, **10,** Jan.-Mar., 57–66). [In Spanish]. The author proposes that this be done by determining the composition and properties of a group of steels that form a minimum number for the requirements of mechanical construction. The general requirements are discussed e.g. hardenability, toughness etc., and a general approach to a system of classification is suggested.—P. S.

Study on High Strength Low Alloy Steel. T. Mishima, Y. Mishima and E. Asano. (*Tokyo University, Annual Report of the Engineering Research Institute*, 1957, **15,** No. 2, Mar., 50–56). [In Japanese]. Low temperature embrittlement of Highstren steel was examined. Cold straightening slightly reduced impact value but a marked increase results on heating to 600° C after straightening. Impact value is reduced by increased C or P but less by Mn. O.H. melted steel is less brittle than electric furnace melted, possibly due to N as addition of Al raised it to the same value.

Materials Question of Prestressed Concrete Steels. B. Ansorge. (*Technik*, 1957, **12,** June, 411–416). Three steels, — 0·85% C unalloyed; 1·05% C and 0·52% Cr; 0·65% C, 1·33 Si, 1·06 Mn; were fully compared in terms of structure, stress–strain diagram and creep characteristics, with the conclusion that the Si–Mn steel was more suitable for prestressed concrete than the others.—J. G. W.

Present Problems of Alloyed Steel Making. E. Szücs. (*Kohászati Lapok*, 1952, **7,** Dec., 265–277). The main principles of alloyed steel making in O.H. and electric furnaces are discussed and a diffusion deoxidizing method in O.H. practice is described. Reference is made to the metallurgical aspects of the utilization of alloyed scrap and metal ores in the steel melting processes. The use of Ti, B and N as steel alloying elements is considered. The introduction of steels with the following chemical composition is suggested: Hot die steel: C 0·35–0·5, Si 0·3–0·5, Mn 0·7–0·9, Cr 1·9–2·2, W 0·8–1·2%; Creep-resistant steel: C 0·12 max, Mn 0·4–0·6, Cu 0·3–0·5, W 0·6–1·0%; Case hardening steel: C 0·12–0·20, Si 0·3 max, Mn 1·1–1·3, Cr 0·5–0·7, W 0·4–0·6, Cu 0·8–1·0%; Antimagnetic steel: C ~ 0·1, Si 0·3–0·5, Mn 21, Cr 15–16, N_2 0·20.—P. K.

Development of Structural Steel St52 in the East German Republic with Particular Reference to the Yield Point. H. Löscher. (*Technik*, 1957, **12,** May, 357–364). An account is given of progressive improvements of their steel designed to reach the D.I.N. specification of mechanical properties General effects of, e.g. addition of Al, restrictions concerning grain size, and the associated mechanical properties are discussed at length with reference to experimental data.

The Development of Low Alloy Steels for Heat Treatment. G. Delbart and A. Michel. (*Bull. Cercle Etudes Mét.*, 1957, **7,** Mar., 115–148). A description is first given of the work of I.R.S.I.D. in this field. Tests have been carried out with Mn–Si, Cr–Mn–Si, Cr–V, with 0·38–0·45% C and also with 0·28–0·32% C steels. Cr–Mn–Si steels were found to show the most promise and further tests with this steel containing Al, Ti, Mo, B and V in small amounts either separately or in combination have been made. The author summarizes the present position concerning low alloy steels. Tables showing the composition and properties of standard French and foreign low alloy steels are reproduced.—B. G. B.

Steels for Use at High Stress Levels. F. Munoz del Corral and L. Alonso Yagüe. (*Inst. Hierro Acero*, 1957, **10,** Jan.-Mar., 72–79). [In Spanish]. After indicating the need of the aircraft industry for alloys with high strength—weight ratios, a review is made of American (the HY-Tuf group) and French (35 NCD 16) developments of very high tensile strength steels.—P. S.

Die Steels. E. Weigl. (*Kohászati Lapok*, 1954, **9,** March, 122–130; April, 154–161). The author reviews the chemical composition on heat treatment of various kinds of cold and hot die steels. Afterwards he comments on the correct use of dies in practice.—P. K.

Low-Nickel Austenitic Stainless Steels. L. F. Spencer. (*Product Eng.*, 1957, **28,** Aug., 135–140). A review of compositions, output, properties, fabrication and corrosion-resistance is given.

Low-Nickel Stainless Steels. J. G. Henderson. (*Chem. Eng. Progress*, 1957, **53,** Aug., 82, 84). A corrosion testing programme is now being undertaken throughout the chemical industry on behalf of the Amer. Standards Assoc.

Boron Rids Steels of Stretcher Strains. P. M. Unterweiser. (*Iron Age*, 1957, **180,** Aug. 8, 79–81). It is predicted that production quantities of non-ageing low carbon steels will become available in a few years time. Experience with boron addition, and techniques and difficulties in using this element to eliminate nitrogen strain ageing from commercial O.H., steels without producing a killed steel, are described.

High-Vanadium Die Steel Developed. P. R. Borneman. (*S.A.E.J.*, 1957, **65,** Aug., 130, 135). Ottawa 60 steel with 12% V, 3¼% C, 1% Cr and 1% Mo is described. It hardens to 65 Rockwell C after quenching from 1750–1800° F.

Higher Vanadium Improves Hot Strength Of Low Alloy Steel. P. Shahinian and J. R. Lane. (*Iron Age*, 1957, **180,** Aug. 1, 91–95). The results of a research programme which investigated the possibility of replacing some of the Mo in low

alloy high temperature steels by V are described. It is concluded that the higher V contents sometimes result in a better alloy, but a higher normalizing temperature is necessary.—D. L. C. P.

The Role of Light Metals in Ferrous Alloys. L. Jeníček. (*Kohászati Lapok*, 1955, **10**, *Ontcde* Dec., 587–588). Reference is made to the Czecho-Slovak heat-resistant alloy *Piroferal* of the following composition C 1·5%, Mn 0·5%, Si 1%, Al 30%, P 0·1% max, S 0·1% max., the rest Fe. This alloy is in the carbide region of the Fe–Al–C equilibrum diagram. It is heat resistant between 1000–1200° C and also resistant to chemical attack by salts e.g. cryolite. It is weldable, its coefficient of thermal expansion is twenty times higher than that of pure iron and its creep resistance is higher than that of Cr–Ni steels. Its spec. gravity is 5·6. Its formability and machinability are bad. Thus it is used in the cast condition for crucibles, case hardening boxes, furnace components, tubes and ladles for molten Al. The high-frequency furnace is suggested for its production.—P. K.

High Speed Steel Production in the East German Republic. K. Werner. (*Neue Hütte*, 1957, **2**, Apr., 214–219). The method of producing high speed steels in Eastern Germany is described with special reference to the remelting of clean alloy scrap in the electric arc furnace, hot melting and vigorous agitation, final addition of Fe–W 1 h before tapping, maintenance of low carbon content, and pouring at a mean temperature of 1460° C.—L. J. L.

A Description of a Brazilian Plant for Special Steels. L. Dumont Villares. (*Eng. Min. e Met.*, 1956, **24**, Nov., 297–301). [In Portuguese]. A brief history of the Aco Villares Co. is given and details of the expansion taking place are discussed. This includes furnaces, presses, forges etc. for a production of 18,000 t per year in the first stage.—P. S.

A Study on 12% Chromium Heat Resisting Steel (2nd Report). T. Akutagawa and T. Fujita. (*Tokyo University. Annual Report of Engineering Research Institute*, 1957, **15**, No. 2, March, 37–44). [In Japanese]. Effects of alloying elements and heat treatment on creep strength, hardness and microstructure are observed. Mo, Nb, W, V, Ti, B and N were examined. The degree of dispersion and amount of carbide is important. Avoidance of delta-ferrite complicates carbide control and N and B are beneficial.

Alloys for High Temperature Applications. Ryan Aeronautical Co. (*Product Eng.*, 1956, **27**, Mid.-Oct., B8–B9). For working in conditions of high temperature special metals are required and details are given of the properties and characteristics of four groups of alloy steels developed for such working conditions.—E. A. C.

New Materials that the Design Engineer Should Know About: Metallic Materials. C. R. Simcoe. (*Mech. Eng.*, 1957, **79**, Aug., 720–724). Compositions and properties of ultra-high-strength steels are included.

Rustless Manganese–Chromium–Nickel Steel for Sinks. L. Morsing. (*Tek. Tidskr.*, 1957, **87**, June 25, 601). A substitute steel known as 7–18–5 and similar to ALSL202 is used. Comparision of cost and properties with 18–8 are given.

Deoxidation of Rimming Steel. A. A. Bezdenezknykh, A. M. Bigeev, E. I. Dikshtein, P. N. Perchatkin and A. I. Sirotenko. (*Stal'*, 1957, (8), 701–707). A new method used in O.H. furnaces at Magnitogorsk for low-C rimming steel consists of adding all the Fe–Mn (not over 1% Si) at the beginning of tapping. This saves Fe–Mn and guarantees a normal boil in the mould. It is not necessary to keep the heat in the furnace after the Fe–Mn is added. Quantitative evolution of the basic factors or degree of Mn loss during deoxidation in 400-t furnaces gave tables for cost accounting for Fe–Mn consumption. Similar tables could be constructed for any capacity and for any grade of rimming steel. Consumption was reduced by 1–1½ kg/t and ladle samples always conformed to the Mn content required.—R. S.

Deoxidation Of Rimming Steel in the Ladle. K. A. Kataeva, D. F. Nagovitsyn and A. A. Lebedev. (*Stal'*, 1956, (12), 1083–1085). [In Russian]. An account is given of the deoxidation of rimming steel with low-Si Fe-Mn. The steel was produced, tapped and teemed under various conditions. The adoption of ladle deoxidation led to a 22–28% economy in the ferroalloy and to a productivity increase of about 1% (through the elimination of deoxidation time in the furnace). The quality of the metal showed no deterioration and Mn was evenly distributed throughout the metal. An important requirement was found to be sufficiently hot metal; the alloy was best added over 1–1½ min. to the ¼-full ladle. 0·40% Mn in the finished metal is recommended.—S. K.

Experiments on Ingot Moulds. B. Körös. (*Kohászati Lapok*, 1952, **7**, Nov., Ontöde 259–264). Experiments on the production, construction and use of ingot moulds are described and the influence of these factors on their life is considered.

A Contribution to the Study of Steelworks Ingot Moulds. The Presentation of the Researches of the Joint Technical Committee on Ingot Moulds. J. Durand. (*Fonderie*, 1957, Feb., 53–55). The work of the joint committee set up by the Institut de Recherches de la Sidérurgie and Centre Technique des Industries de la Fonderie to study the problems associated with steelworks ingot moulds is reviewed and a brief introduction is given to the papers following.—B. C. W.

A Study of the Behaviour of Ingot Moulds. M. Cetin. (*Fonderia Ital.*, 1957, **6**, May, 193–200). [In Italian]. The exacting conditions of temperature, stress and usage which ingot moulds have to stand up to are described. Mould wear is considered and mould defects and their frequency are isted and commented upon.—M. D. J. B.

New Test Results on Ingot Moulds. G. Bauer, J. Duflot, and A. Gibeau. (*Fonderie*, 1957, Feb., 64–79). Data for the year 1955 from 22 steelworks using the Thomas process are analysed to show the relationship between the consumption of cast iron ingots moulds and the ratio L/l where L is the weight of the mould and l the weight of the ingot. The results are compared with the previous data obtained in 1951. Detailed results are also given on the incidence of cracking in several groups of ingot moulds. Five types of cracks are distinguished and the occurrence of these is discussed in relation to the method of manufacture employed for the moulds and the conditions under which they were used. The relationship between chemical composition and mould cracking is also considered with particular reference to the Si/Mn ratio and the effect of trace elements.—B. C. W.

The Structure of Steelworks Ingot Moulds Before and After Use. M. Ferry. (*Fonderie*, 1957, Feb., 55–63). The metallographic structure of 20 new and 10 used ingot moulds is described and discussed. The moulds are classified according to the mount of ferrite present in the structure. During service, oxidation of the internal mould face, and spheroidization and graphitization of the pearlite occurs. The extent of surface oxidation depends on the amount of ferrite present and is only pronounced if extensive carbide spheroidization and graphitization takes place. Structures containing little ferrite were found to show little tendency to graphitize in service.—B. C. W.

A Contribution to the Study of the Macrostructure and Microstructure of the Grey Iron Used for Steelworks Ingot Moulds. M. L. Beaujard and S. Béchet. (*Fonderie*, 1957, Feb., 80–89). The results of a metallographic study on test castings poured from the same heats that were used to cast ingot moulds, are presented and discussed. Particular attention was paid to the form of the sulphide inclusions. Disc castings 90 mm and 150 mm dia. were used and the effect of section size on the structure was also studied by using a series of square section castings.—B. C. W.

Heating and Cooling Curves for Growth Experiments with Different Ingot Mould Irons. B. Körös. (*Kohászati Lapok*, 1955, **10**, March, 41–44). In order to obtain adequate results from growth experiments on different ingot mould irons, it was necessary to plot heating and cooling curves of ingot moulds for 1, 2 and 3 hours stripping times. Based on this work it was possible to settle the cyclic thermal diagrams for the investigations planned.—P. K.

Influence of the Composition of the Charge and the Chemical Composition of the Iron on Mould Life. I. E. Brainin, S. I. Shapovalov, R. I. Budinshtein, V. A. Kharchenko and E. E. Belousova. (*Stal'*, 1956, (12), 1110–1115). [In Russian]. The following are the main conclusions drawn from an analysis of extensive data on the life of moulds with various compositions and produced from various charges: the composition and quality of the charge is the main factor influencing open-mould life; the life does not decrease if up to 15% of foundry iron is replaced by basic iron with suitable additions of blast-furnace ferrosilicon; the influence of the change in the life of closed moulds is also appreciable but is much less than for open moulds. Composition and structures for various types and sizes of mould are recommended.—S. K.

The Dendritic Segregation of Manganese in Steel Ingots. R. G. Ward. (*J.I.S.I.*, 1958, Apr., **188**, 337–342). [This issue].

Developing of Crazing in Ingot Moulds. N. I. Pavlovtseva and L. M. Cherkasov. (*Stal'*, 1957, (9), 800–804). "Burnt crack networks" which appear at the beginning of the first third of the life of moulds are internal surface defects penetrating to a marked depth and being a source of longitudinal and transverse cracking. Intensive development spoils the ingot and causes sticking in the mould. The cause is probably propagation of surface layer stresses. Alloying with Cr retards its development and has other advantages; 6-t moulds with 0·1–0·2% Cr and 1·8% minimum Si had a life of 53 casts as against 44 without alloying. In nodular graphitic moulds the life was 79 casts, crazing was very fine and only 2–4 mm deep and they were used without external banding.—R. S.

The Effect of Mould Design on Corner Cracks in Ingots. S. Ogawa. (*Tetsu to Hagane*, 1957, **43**, Mar., 331–333). [In Japanese]. Data are analysed statistically to show the effects on corner cracking of mould design (varying corner radii), order of pouring, chemical composition of the steel, and some test conditions.—K. E. J.

On the Thermal Cracking and Hardness of Ingot Mould Iron. II. Y. Ogiwara. (*Tetsu to Hagane*, 1957, **43**, Mar., 207–209). [In Japanese]. An inverse linear relationship is shown between thermal cracking and the life of the mould. At Rockwell–B hardness of approx. 75, the mould life is at a maximum and thermal cracking at a minimum. The lowest values of thermal cracking are found for annealing times between 0 and 3 h.—K. E. J.

On the Molten Steel Stream at Tapping or Teeming. I. Y. Koike. (*Tetsu to Hagane*, 1957, **43**, Mar., 285–286). [In Japanese]. After comparisons between the surface tension of Fe, Hg, and water, laboratory tests on the flow behaviour of streams of water, solutions of glycerol and ethanol, and Hg from vertical orifices are described, and results given.

Relations between Teeming Conditions of Semi-killed Steel Ingots and Their Sub-surface Blow-holes. T. Kato. (*Tetsu to Hagane*, 1957, **43**, Mar., 288–290). [In Japanese].—K. E. J.

Deoxidation of Rimming Steel by Addition of Ferromanganese in the Ladle. D. S. Gerchikov, A. M. Ofengenden and L. M. Pokrass. (*Metallurg*, 1957, (6), 13–15). Rimming steel is produced at Stalinsk in mixed gas-fired all-basic O.H. furnaces charging 60–65% hot metal. The steel is uphill cast into 0·9–3·4 t ingots and variations in S and P content and Mn losses are reported for various methods of deoxidation. With deoxidation in the ladle the metal temperature at tapping must not exceed the normal for deoxidation in the furnace (1600–1620° C). Only high-S steels are now deoxidized in the furnace, the saving of Fe–Mn by use in the ladle exceeds 600 t.—R. S.

Elimination of Hydrogen and Nitrogen in Molten steel with Argon and Oxygen Flushing. III. M. Imai. (*Tetsu to Hagane*, 1957, **43**, Mar., 227–228). [In Japanese]. Details are given of the variation of H_2 content during refining of several low-alloy and plain-carbon steels, and its reduction through argon blowing. Relationships are shown between the flushing volume of A and the H_2 content, and between the partial pressure of water in the air and the H_2 content of the steel.

The Repair of Casting Pit Cast-Iron Equipment by the Thermit Process. A. M. Hamilton. (*J. West Scotland Iron Steel Inst.*, 1956–7, **64**, 267–281). Repair of moulds, slag tubs and ladles, and casting cars is described and economies in the repair of items which had been discarded for relatively small faults are pointed out. Details of preparation for welding as well as the processes of repair are given.

The Safe Coupling of Ingot Casting Cars and Scrap Pan Bogies. R. L. Willott, P. E. Holloway, C. Moody, F. D. Ackerman, J. C. Dayson, W. R. Hockaday, J. Liddell, W. H. Schofield and G. K. Tatterson. (*British Iron and Steel Federation Publication*, [1957], pp. 40). Principles to which couplings should conform are set out, with illustrations and diagrams of various designs and hazards in their use.

An Investigation of the Continuous Casting of Steel using Radioactive Indicators. B. N. Katomin and V. S. Rutes. (*Izvest. Akad. Nauk, S.S.S.R. Otdelenie Tekh. Nauk*, 1957, (1), 123–135). [In Russian]. An investigation of heat exchange processes and crystallization of steel during continuous casting was investigated. Of particular interest was the problem of the dependence between the depth of liquid phase ("cone" of liquid metal), the distribution of front and velocity of crystallization in the continuous ingot on the amount of heat removed and velocity of withdrawing, intensity of cooling, physical properties of metal and some special design features of the casting equipment. Radioactive ^{32}P and ^{35}S were used for investigation of the crystallization process. For exact positioning of the bottom of the liquid metal, additions of liquid lead were made immediately before the introduction of radioactive tracers. The experimental procedure is described in some detail. On the basis of the results obtained the following conclusions were drawn: (1) the formation of the solid crust of the ingot in the mould takes place according to the same laws as the growth of the crust during solidification of a steel ingot in an ingot mould during the initial stages of crystallization; (2) the value of the mean solidification coefficient depends on the penetration of water into the clearance between the ingot and the walls of the mould which leads to an increase in the thickness of the crust at the outlet from the mould; (3) the gaseous layer in the clearance between the surface of the ingot and the walls of the mould caused by shrinkage has a decisive influence on the removal of heat and the crystallization of steel in the mould. Thermal resistance of this layer presents 90% of the total resistance of the system; (4) mean velocity of solidification of the ingot in the zone of secondary cooling is independent of the intensity of secondary cooling; (5) secondary cooling is technologically correct when the length of the cooling zone secures the end of solidification of the ingot in this zone. The cooling water should be supplied uniformly in such quantities as to obtain a continuous fall in temperature of the surface up to the completion of solidification, but not below the temperature of the zone of elastic deformations.

Studies on the Improvement of Steel Properties by Treatment [with Titanium-containing] Slag. T. Shimose. (*Tetsu to Hagane*, 1957, **43**, Mar., 357–359). [In Japanese]. Details are given of the chemical composition and casting conditions of ingots containing between 0 and 0·5% Ti. Results are given of hot-workability tests on these ingots.—K. E. J.

Study on the Solidification Structure of Steel Ingots. I. Effect of Carbon and Silicon Contents. A. Inoue. (*Tetsu to Hagane*, 1957, **43**, Mar., 365–366). [In Japanese]. Test ingots were prepared, one side being cooled rapidly and the other slowly, the axis of the ingot being vertical. The columnar, dendritic and equi-axial crystalline zones are traced on a longitudinal section, and the variations of these with carbon content up to 1·00% and Si content up to 5·50% are explored.—K. E. J.

Study on the Solidification Process of Ingots. II. Relation between Chemical Composition of Molten Steel Adjacent to the Solid Metal during Solidification and Segregation. Y. Nakagawa. (*Tetsu to Hagane*, 1957, **43**, Mar., 286–287). [In Japanese]. By means of a thorough sampling scheme at different levels and depths in the ingot, comparisons are made between the molten steel during solidification and the final ingot for C, Si, Mn, P, S, H, O and N contents.—K. E. J.

Studies on the Solidification and Segregation of Larger Steel Ingots. III. A Unified and Systematic Interpretation for the Mechanism of Formation of the Three Major Segregations. S. Onodera. (*Tetsu to Hagane*, 1957, **43**, Mar., 330–331). [In Japanese].—K. E. J.

On Air Gap Formation during Ingot Solidification. J. Imai. (*Tetsu to Hagane*, 1957, **43**, Mar., 333–335). [In Japanese]. Cooling data are given showing the temperatures of the ingot surface and mould surface after pouring; the temp. difference after 4 min reaches a value, which remains constant up to 12 min. The heat flow from ingot to mould after formation of the air gap is shown for varying times. The time for formation of the air gap is a minimum (approx. 40 sec) for an initial mould temperature of approx. 120° C.—K. E. J.

Avoiding Whisker Formation During Steel Recrystallization by Addition of Rare Earth Elements. V. M. Tageev and Yu. D. Smirnov. (*Stal'*, 1957, (9), 823–828). Whisker formation is due to sulphur accumulations varying the solubility in the solid and liquid phases. Re-oxidized liquid steel was treated with Ce or La or other rare-earth elements, 0·1–0·2%, and the sulphide phase then precipitated at an earlier stage, thus diminishing the redistribution by diffusion in the 2-phase zone. Much of the S deposits in the dendrite axes. More uniform distribution of P also occurs by reduced migration into the liquid phase probably due to increased viscosity from S reduction.—R. S.

Studies of Sand Mark. M. Kamiya. (*Tetsu to Hagane*, 1957, **43**, Mar., 415–416). [In Japanese].—K. E. J.

On the Surface Defects of Bottom-poured Killed Ingots. H. Iwata. (*Tetsu to Hagane*, 1957, **43**, Mar., 290–292). [In Japanese]. The frequency of occurrence of defects (refractory inclusions, slag patches, brick inclusions and skin holes) is analysed between the top and bottom of an ingot for a given position in the mould stool. The occurrence of these defects is also related to that of surface defects for different positions in the mould stool, and for three mould stools.

FOUNDRY PRACTICE

Three Foundries in the Irish Republic. V. C. Faulkner. (*Found. T. J.*, 1957, **103**, Oct. 24, 497–498). The Hammond Lane Foundry Co. of Dublin and Sligo, the I.V.I. Foundry Ltd. of Athy, Kildare and Tonge and Taggert Ltd., Dublin are briefly described.

Towards Automation in the Foundry. W. Gesell. (*Fonderie Belge*, 1957, June, 133–144). The extent to which it may be possible to employ mechanization and automation in the various departments of a foundry is discussed with particular reference to moulding operations.—B. C. W.

Rational Modernisation of Foundries. A. M. Plesinger. (*Slévárenství*, 1957, **5**, (8), 225–231). [In Czech]. Improvements in the degree of mechanization need to be of a specific type, depending upon the degree of mechanization already present, if full advantage is to be made of them in terms of productivity. This and other problems relating to the most rational ways of modernizing and organizing foundry work are discussed.—P. F.

Welded Grab of a Foundry Crane to Lift 160 t with Gearbox Designed as a Load-Carrying Component. H. Andres. (*Schweissen u. Schneiden*, 1957, **9**, June, 261–262). A description is given of a foundry crane grab in which the welded gear box forms a load carrying unit of low overall height and pleasing appearance.—U. E.

The Basic Cupola. F. Varga. (*Kohászati Lapok*, 1953, **8**, *Ontode*, Oct., 205–213). The development, practice and economy of basic lined cupolas and the different methods of desulphurization and dephosphorization by increasing the slag ratio are discussed with reference to the latest publications.—P. K.

The Basic Cupola—Its Design and Operation. J. H. Cannon and A. L. Bradley. (*Engineer and Foundryman*, 1957, **22**, July, 55–60; discussion, 60–62). Factors in design, materials, conductivities, lining methods, including rammed monolithic linings, and the use of dolomite in South Africa, slag composition and viscosity, reactions in the cupola, including sulphur relationships, Si and Mn losses, improvements in design and saving in refractories, blast control and analytical findings and slag observation are all outlined.

Effect of Atmospheric Humidity on Cupola Practice. E. Chapo. (*Kohászati Lapok*, 1955, **10**, March, 54–59). The determination of air required for burning the coke, the relation of the melting rate to the blast at various temperatures and pressures and the influence of atmospheric humidity on cupola practice and iron properties are discussed. A short description is given of a dehumidifying equipment.—P. K.

Cupolas with Thermal Recuperation. M. Dieterle. (*Tecn. Indust.*, 1956, **34**, Dec., 1798–1800). [In Spanish]. The 'Arpi' system of recuperation is described together with the advantages of using pre-heated air, i.e. increased production, decreased coke consumption and smaller sulphur contents of the irons. The pre-heated air temperature is about 400° C.

How to Increase the Melting Capacity of Cupola Furnaces by Using HC-Coke. G. Speer. (*Giessereitechn.*, 1957, **3**, July, 151–152). The Sales Association for Tar Products (VfT) in Essen are now producing high-carbon coke under licence. The chemical and physical characteristics of this coke, as described in the trade literature, are discussed. Brief instructions for its use are given.—L. J. L.

The Hot Blast Cupola and its Present State. F. Varga. (*Kohászati Lapok*, 1954, **9**, Jan., 1–9). The advantages of the hot over the cold blast cupola are as follows: (1) 30–40% decrease in coke consumption. (2) Increase in output. (3) Lower melting loss in Mn and Si with consequent saving of ferromanganese and ferrosilicon. (4) Lower S and higher C content as well as finer graphitization in grey cast iron, all leading to a better quality.—P. K.

Separately Heated Air Preheaters for Cupolas. V. Almborg and T. Bratt. (*Gjuteriet*, 1957, **47**, (1), 9–10). [In Swedish]. Details are given of a new type of Swedish air preheater for use where melting times do not exceed 3 hr. The blast is preheated in cross-flow by waste gases from an oil-fired furnace. Data are: volume 4000 m^3, oil consumption 70 kg/h fan power 12 kW, pressure drops on blower and flue gas sides 90 and 25 mm W.G., efficiency 80%, total weight 30 t.—G. G. K.

A New Metallurgical Melting Furnace Without Checkers Using Oxygen for the Combustion of Gaseous, Liquid, or Solid (Finely Ground) Fuels. (*Stahl u. Eisen*, 1957, **77**, May 16, 651–652). A furnace of 1500 kg capacity for the melting of steel scrap and pig iron using O_2 for the combustion is described. The stirring effect of the flame is excellent and can be varied within a wide range. The heat input amounts to 650–700 kcal/kg charge, the O_2 consumption is about 140 m^3 (N.T.P.)/t charge. The quality of the steel produced was good, O, P, and S contents were low and H_2 content was extremely low. The N_2 level was the same as in O.H. steel. A furnace of 10–15 ton capacity is under construction.—T. G.

Operating Experience with Retractable Tuyeres for Blowing Oxygen into the Fore-Hearth. V. A. Fuklev. (*Liteĭnoe Proizvodstvo*, 1956, (8), 4–5). [In Russian]. A bogie-mounted, refractory covered tuyere designed to fit into the tuyere port in the cupola fore-hearth is described and some information on operation and maintenance is given. Visual or sonic indications are given of refractory wear.—S. K.

The Mains Frequency Induction Furnace for the Production of Cast Iron. G. A. Tagliaferri. (*Inst. Hierro Acero*, 1956, **9**, Oct.-Dec., 1067–1080). [In Spanish]. After listing the advantages of this type of furnace, the author discusses four different installations, producing different types of cast irons, with particular reference to the furnace type, the operating conditions, and the mechanical properties and microstructures of the product in each case.—P. S.

Electric Furnaces for Metal Melting. Major Electric Furnaces Pty. Ltd. (*Chem. Eng. Min. Rev.*, 1957, **49**, June 15, 57–60). A brief review of types and their uses.

Induction Melting Furnaces. K. H. Brokmeier. (*Elektrowärme*, 1957, **15**, Mar., 99–103). A review, comparing mains-frequency ring furnaces and crucible furnaces and medium-frequency crucible furnaces for cast iron, steel, and heavy and light metals.

A Consideration of the High-Strength Grey Cast Irons. E. Diaz-Varela. (*Tec. Met.*, 1956, **12**, Nov.-Dec., 210–216). [In Spanish]. This article, from '*La Fonderie Belge*' June, 1954, reviews the relationship between tensile strength and microstructure of cast irons. It also lists their useful properties.

Critical Summary of Hungarian Research for the Production of High Strength Cast Iron. J. Verö. (*Kohászati Lapok*, 1952, **7**, Aug., *Ontode*, 169–188). Research for the production of high strength cast iron is summarized, and full scale experiments with Mg inoculation and modification with ferrosilicon are suggested.—P. K.

Study on High-strength Cast Iron. I. Iitaka and K. Nakamura. (*Rep. Castings Res. Lab. Waseda Univ.*, 1956, Oct., 13–15). [In English]. The relations between chemical composition (C and Si), strength and hardness are examined for irons produced in the cupola from steel scrap. It is necessary to keep both C and Si contents below some definite values to obtain high strength, but it is difficult to estimate strength directly from composition because small changes in the graphite structure affect the strength greatly. Cast irons having a soft matrix and a graphite condition which raises the Brinell hardness generally have high strengths.—K. E. J.

On Heredity of Pig-iron. II. Effects of [Bubbling Various Gases] into Molten Pig-iron. I. Iitaka, K. Nakamura and M. Kikuchi. (*Rep. Castings Res. Lab. Waseda Univ.*, 1956, Oct., 1–5). [In English]. "Heredity" refers to the effect on the amount of added magnesium needed for spheroidization, and results are given for H_2, O_2 and A bubbling, and some bubbling of both H_2 and O_2, through Swedish charcoal iron and some Japanese irons. Purely mechanical bubbling, as with argon, shows some improvement by removing oxides and elements which inhibit spheroidization to the surface and into the slag. H_2 causes additional improvement by decreasing the S concentration and reducing oxide inclusions. O_2 has a detrimental effect, as it increases the content of inclusions.

Nodular Graphite Cast Iron. D. Iturrioz. (*Met. Elect.*, 1957, **21**, May, 57–64; June, 83–90). [In Spanish]. A brief historical review of the cast irons is given and followed by an account of the characteristics, mechanical and physical properties, foundry techniques and applications of nodular cast irons.

Cast Iron and Nodular Cast Iron. (*Tec. Indust.*, 1956, **34**, Oct., 1465–1472). [In Spanish]. The constitution of the cast irons is reviewed in detail, and an account of the inoculated irons is also included.—P. S.

How To Check Quality in Ferritic Nodular Iron. H. Mansfield. (*Iron Age*, 1957, **180**, Aug. 8, 88–91). The results of a study of how chemistry, microstructure and internal defects affect the properties of ferritic nodular iron ("60–45–10") are described. It is concluded that the basis for acceptability of nodular iron castings should be a combination of X-ray and metallographic inspection; a series of illustrations is used to explain the interpretation of these tests.—D. L. C. P.

Primary Structure of Grey Iron Treated with Magnesium. P. I. Sztyepin. (*Kohászati Lopak*, 1952, **7**, Oct., *Ontode*, 217–224). Russian experiments with Mg treatment of grey iron are described and the role of Mg in the formation of spheroidal graphite is explained theoretically.—P. K.

Experiments on the Production of Nodular Iron Castings. M. Cseh. (*Kohászati Lapok*, 1955, **10**, Oct. 236–241; Nov. 274–283). Based on Hungarian small scale experiments the author discusses the effect of chemical composition and inoculation methods on the mechanical properties and microstructure of nodular cast iron. For achieving high impact values the Si, Mn and P contents should be as low as possible. Information is given about the heat treatment i.e. annealing, normalizing, hardening and tempering. The moulding technique for small castings and the charging of fluxes are described. The author comments on the economy, advantages and disadvantages of nodular iron castings. They can generally replace malleable iron castings and in many cases steel castings or heavy metal castings.—P. K.

The Retarding Effect of Metallic Impurities on the Formation of Globular Graphite. J. Piaskowski. (*Kohászati Lapok*, 1955, **10**, Nov., 261–269). Al and Ti retard the formation of nodular graphite, but this effect can be eliminated by increasing the Mg content. The retarding effect of Sb, Bi and Pb is essentially higher. It can eventually be neutralized only by the simultaneous addition of CeO_2 and Mg. Sn has no effect on the formation of nodular graphite.—P. K.

Increasing the Productivity of Large Cast-Iron-Melting Cupolas Working on Cold Blast. S. E. Bark, L. M. Martynovskii and M. I. Skvortsova. (*Liteinoe Proizvodstvo*, 1957, (1), 20–21). [In Russian]. Experience with the use in cold-blast cupolas of a higher blowing rate without increase in tuyere cross-section area (0·31 m²) at a grey iron foundry in Moscow is described. The internal diameter of the cupola was 1600 mm, its effective height 6000 mm and there were two rows of eight tuyeres. The specific blowing rate was increased from 100 to 120–130 m³/m² of charge cross section, the effects produced including the following: fall in top-gas CO_2-content from 8·8 to 8%, rise in CO-content from 15·2 to 20·2 to 20·3, fall in N_2 from 75·0 to 70·7. Water cooling of the fusion bell was introduced and details of this and other measures are given.—S. K.

A New Hot Blast Cupola with Direct Recuperation of the Heat of the Exhaust Gases. G. Ulmer. (*24th International Foundry Congress Papers*, 1957, (2), 643–668). A design with recuperator on top of the furnace is described and details of instrumentation are given. A 500 mm cupola was built and tested and results of a 6 month's run are given. Melting capacity increased 30%, coke consumption fell 25% and iron temperature was raised 20–30°.

The Melting Process and Material Balance of a Hot Blast Cupola. S. Forssell and Y. Ingman. (*24th International Foundry Congress Papers*, 1957, (2), 669–690). Fluctuations in furnace operation are observed in the temperature and composition of the iron and in the composition of slag, but the CO_2 content of waste gases is most suitable for control. Composition of slag depends greatly on contact time with coke in the hearth. Ferrous oxide contents are correlated and iron droplets in slag are discussed and analysis shows that they are probably formed in it by reduction. Flue dust is examined, the fine dust being of special interest, various elements being concentrated in it.

Theory of Carbon Pick-up in the Cupola. R. Krzeszewski. (*24th International Foundry Congress Papers*, 1957, (2), 497–524). Various observations are recorded, pick-up depends upon iron composition, kind of coke and ash content, temperature attained and coke consumption as well as other factors and generalization is prevented by lack of information on kinetics. Experiments on C diffusion to Fe–Si alloy suggested a form of pick-up equation and assuming an oxidizing atmosphere an expression for the cupola is advanced of which Levy's formula is a particular case.

Silicon Variations in Cast Iron Melted in Cupolas. J. Drachmann. (*24th International Foundry Congress Papers*, 1957, (2), 525–557). Silicon content was measured at the syphon of a continuous cupola at intervals of ~ 2 mins and no trend was observed with constant melting conditions, no cyclic component related to charging appeared, but a fluctuation about a mean is found related to charge heterogeneity. Mechanisms are discussed and an attempt is made to combine the whole into a mathematical model for cupola operation. Practical advice for reducing variations is added.

Control of Cupola Gases. W. Y. Buchanan. (*Foundry Trade J.* **103**, Sept. 12, 319–320). Notes on dangers from CO in cupola operation are given. Procedure for safe working with the use of spark-arrestor and fan is outlined.

Spark-Extinguisher for a Cupola. D. S. Soskin. (*Liteinoe Proizvodstvo*, 1956, (11), 28–29). [In Russian]. A brief account is given of a device which, when attached to a cupola, extinguishes glowing fuel dust particles practically completely. The device is essentially a horizontal chamber.—S. K.

Oil Fuel in the Foundry. J. L. Rundle. (*Inst. Brit. Found.*, 1956, **7**, 49–64). Crucible furnace combustion and heat transfer processes are discussed, with suggestions for improving efficiency. Direct melting furnaces and core ovens are then reviewed.

Electric Arc Furnaces for Melting Metals in the Foundry Department of the Silesian Polytechnic. S. Jarzebski and E. Horoszko. (*Przeglad Odlewnictwa*, 1957, **7**, March, 61–65). [In Polish]. The features and technical data of an arc furnace designed and constructed by the Department of Foundry Engineering in the Silesia Polytechnic are given. Prototypes of 50 and 10 kg furnaces have been operated since October, 1955 and the 250 Kg furnace since March, 1956.

The Importance of Induction Furnaces for the Foundry. K.-H. Brokmeier. (*24th International Foundry Congress Papers*, 1957, (2) 691–715). Crucible furnaces are reviewed and their use for cast iron considered. Temperature control and operation technique as well as economic aspects are reported. Analyses of synthetic melts are given.

Low-Frequency "Russ" Induction Furnaces and their Uses in the Foundry. (*J. Foun. Elect.*, 1957, May-June, 105–109). Types of furnaces with their capacities are described with special reference to duplex and foundry uses.

Preparation of Ductile Black Cast Iron in Basic Electric Furnaces. A. Ludovic. (*Met. Constr. Masini*, 1956, **8**, (2), 86–91). A detailed description is given for the preparation of this material in a Heroult-type electric arc furnace of 1½ t capacity with basic lining. After suitable heat treatment, the finished product was submitted to tensile tests. The results show that the test specimens of a diameter of 16 mm and of a length of 50 mm had a resistance to rupture of 30–40 Kg/mm² and an elongation of between 8–16%.—L. H.

High-Strength Cast Iron with Granular Pearlite. M. V. Voloschchenko. (*Liteinoe Proizvodstvo*, 1957, (1), 17–18). [In Russian]. A brief account is given of an investigation of the influence of Mn on the graphitization of high-strength cast iron. A Mn content of 1·2–1·6% is recommended for irons with 1·8–2·2% Si for giving a granular pearlite structure. Heat treatment conditions are noted and microstructures are illustrated.—S. K.

Possibilities of Casting Grey Pig Iron and Ductile Iron in Chill Moulds. F. Naumann. (*Przeglad Odlewnictwa*, 1955, Dec., 353–358). [In Polish]. The practice and advantages of the casting of grey pig iron and ductile iron in chill moulds in Germany are briefly described. The chill moulds used are made of grey cast iron and their working life is between 1000 and 5000 castings. A few practical points relating to the chill moulds and casting in them are given. Various types of chill moulds and some castings obtained are illustrated.

The Production and Utilization of Spheroidal-Graphite Iron in West Germany. J. Wojcik. (*Przeglad Odlewnictwa*, 1957, **7**, March, 76–83). [In Polish]. The different type of spheroidal-graphite iron and their properties are discussed and a wide range of application is given. The author describes the melting furnaces and charges and gives a detailed account of the two methods mainly used: the "sealed ladle" method and the "lance injector."

Distribution of Magnesium in Cast Iron with Spheroidal Graphite. I. L. Mirkin and E. P. Rikman. (*Liteinoe Proiz-*

vodstvo, 1956, (12), 22–25). [In Russian]. The authors have used their method of localized spectral analysis with linear sources, to study local (0·013 mm²) Mg contents at various points in specimens of Mg-inoculated spheroidal-graphite iron. The composition ranges of the irons used were: 0·029–0·104% Mg, 2·96–3·40% C, 2·02–2·96%; Si, 0·48–0·84% Mn, 0·096–019% P, 0·004–0·020% S, 0–0·14% Cr. The microstructure of the metallic part ranged from pearlite to ferrite with 5% pearlite. Results showed that very localized concentrations of Mg often greatly exceed or fall below the average.—S. K.

On the Metallurgy of a High-Quality Cast Iron with Formation of Compact to Spheroidal Graphite. E. Piwowarsky and E. G. Nickel. (*Forsch. Wirts. Nordrhein-Westfalen*, 1956, No. 348, pp. 46). Overheating of the melt and deoxidation as a method of production is discussed and treated mathematically and the same process under basic conditions. De-gassing by nitrogen treatment and *in vacuo* and its effect on structure is described, and various deoxidant additions are considered with their effects on the form of graphite produced. (16 references).

Smelting Magnesium Cast Iron in a Charge with a High Steel Content. S. I. Ryabukhov. (*Liteinoe Proizvodstvo*, 1956, (12), 30). [In Russian]. A brief account is given of the cheap production of a low-P cast iron by using a large proportion of steel instead of hematite iron in the charge. The iron was treated with Mg under a special hood. The low P content ensured a tough product.—S. K.

The Influence of Phosphorus on the Casting Properties of Cast Iron with Spheroidal Graphite. L. Sofronie. (*Met. Constr. Masini*, 1956, **8**, (7), 45–52). In contrast with grey cast iron, P has a very great influence on the mechanical properties of spheroidal graphite cast iron. An examination lists these influences under the various headings such as its influence on the structure, fluidity, linear contraction, volume contraction etc. The conclusions reached show that P in this type of cast iron increases the tendency to crack at high temperatures so that it must be kept within well determined minimum values.—L. H.

The Influence of Phosphorus on the Mechanical Properties of Nodular Graphite Cast Iron and on Its Resistance in Use. L. Sofronie (*Met. Constr. Masini*, 1956, **8**, (5) 32–38). A description is given of tests made to determine the influence of P on nodular graphite cast iron in concentrations between 0·008–1% in pearlite and ferrite structures respectively. The conclusions point to the fact that nodular graphite cast iron with a high P content, over 0·3%, is more resistant than cast iron poor in P and that it has better mechanical properties.—L. H.

On the Formation of Spheroidal Graphite in Cast Iron. K. Grütter. (*Roll'schen Mitt.*, 1955, **14**, Jan.-Dec., pp. 62; published July 1957). The author reviews current theories on the formation of s.g. in cast iron. These theories indicate that changes in the physical properties rather than in the chemical properties of the iron lead to its formation. The author determines the surface tension of various irons of different compositions by a modified capillary-depression method, which is described. The surface tension of molten iron is mainly a function of the S content; high S content lowers the surface tension. He considers the effect of surface tension on the shape of the graphite in cast iron. The diffusion rate of C was also determined. He found that the diffusion rate is higher in s.g. iron than in ordinary grey cast iron. (54 references).—T. G.

Effect of Gas Scavenging on the Magnesium Consumption in the Production of Spheroidal Graphite Cast Iron. W. Patterson. (*Giesserei*, 1957, **44**, Apr. 25, 216–227). The mechanism of the scavenging effect is first described and the treatment of cast iron melts by gas scavenging is discussed. The salient questions are: can the amount of magnesium used be reduced by gas scavenging, and can the effect of interfering elements be suppressed by this method? These two aspects are considered separately in some detail. Comments are made on gas scavenging technique and a contribution is made to the crystallization of spheroidal graphite.—R. J. W.

Graphitisation of Liquid Cast Iron by Gas Scavenging. G. Blanc and N. Volianik. (*Giesserei*, 1957, **44**, May 9, 277–290). A review is made of earlier work in this field (30 references). The principle of the method is described and the results of small scale experiments tabulated and illustrated. Possible application of the method in the works is described and six detailed examples of its use are given. Finally the advantages of graphite formation by gas scavenging are enumerated and discussed.—R. J. W.

Condition of the Production of Nodular Cast Iron. I. Karsay. (*Kohászati Lapok*, 1953, **8**, Feb., *Öntöde*, 25–30). A comprehensive review is given of the principles and conditions of spheroidal graphite formation. The heat treatment, the mechanical and physical properties as well as the applications of nodular cast iron are also reported.—P. K.

Aspects of Charge for Nodular Cast Iron. Gy. Nándori (*Kohászati Lapok*, 1954, **9**, Jan. 9–17). The author reviews the influence of inclusions and gases on the separation of graphite in cast iron as well as the correlation of carbon content and tensile strength. A high scrap content up to 70% is necessary in the cupola mixture to obtain an iron with low carbon content and high tensile strength. The Russians specify a carbon content of about 2·8–2·9% in nodular cast iron. Also reference is made to the metallurgical and economic advantages of reverberatory furnaces and high-frequency furnaces over cupolas in the production of nodular cast iron.—P. K.

The Production of Malleable Cast Iron with Various Structures. M. Csiszár. (*Kohászati Lapok*, 1952, **7**, July, *Öntöde*, 159–167). The charging in the cupola furnace, moulding and casting, heat treatment and use of white, all black and blackheart malleable irons are described and the chemical composition, mechanical properties and microstructures specified.

Practical Experiences with Modified Blackheart Malleable Iron. J. Lajtay. (*Kohászati Lapok*, 1954, **9**, April, 79–84). The most suitable chemical composition of blackheart malleable iron is as follows: C 2·4–2·7%, Si 0·9–1·3%, Mn 0·4–0·7%, S 0·16% max., P 0·10% max., Cr and Si 3·7–4%, Mn 3 × S + 0·25% min. A white cast iron was melted with lower Si content in a cupola furnace and the above specified Si content was obtained by inoculation in the top spout with ferrosilicon of grain size 2–6 mm and 75% Si content, preheated at 900° C. Steel casting components of various machines can be replaced in many cases with blackheart malleable iron castings, produced by this method.—P. K.

Salt-Bath Graphitization Applied to High-Sulphur Irons. O. Bader and D. Godot. (*Foundry Trade J.*, 1957, **103**, Aug. 15, 195–197). The advantages of the salt-bath furnace and tests on high-S irons are reported. Two stages were employed, salt bath treatment at 1050° C and transfer to an atmosphere-controlled tar-oil-fired furnace for partial ferritization at 760–720° C at a rate of 5°/hr. Small castings required 50 min in the first and 8–10 hr in the second stage.

A New Method of Cast Iron Modification. B. Körös. (*Kohászati Lapok*, 1952, **7**, Dec., *Öntöde*, 285–286). A Russian method is described which consists of the mixing of molten white and grey cast irons in the ladle. The best mechanical properties have been obtained from a mixture of 20–30% grey and 80–70% white.—P. K.

Saving Material and Reducing Scrap in Malleable-iron Foundries. J. Kotzur. (*Giessereitechn.*, 1957, **3**, May, 107–108). The mode of action, position, and dimensions of conventional feeders with cup-shaped base sections are critically discussed. The use of feeders with only slightly curved bases and of carefully calculated cross section and wall thickness is advocated.—L. J. L.

Air Cooled and Oil Quenched Pearlitic Malleable Irons. J. E. Kruse. (*Product Eng.*, 1956, **27**, Mid-Oct., B2–B5). The results of tests carried out to determine the mechanical properties and machinability of pearlitic malleable iron are described. It is shown that oil quenched and drawn iron exhibits a higher yield strength and greater elongation but lower cutting resistance than when air cooled and drawn.

Pontiac Experience Yields Comparative Data on Cast Pearlitic Malleable Iron and Forged Steel Crankshafts. K. B. Valentine. (*S.A.E.J.*, 1957, **65**, Aug., 75–76). Elasticity, fatigue tests and the effect of cold-work on impact fatigue are outlined.

The Metallographic Phenomena of Malleablizing. F. Boda. (*Kohászati Lapok*, 1953, **8**, Nov., 238–243). The author refers to the main principles of malleablizing which are the dissolution of cementite at higher temperatures and that of pearlite at lower temperatures. For shortening the process the following conditions are required: (1) Low C, Mn and S; (2) adequate Si and P contents. Numerical data are given for these. The nucleating effect of Ni, Cu, Al, Zr, Ti and B also accelerates malleablizing. The process is retarded by Cr, Te, Sn, Sb, Mn and Mo, which decrease the diffusion rate of C.

Russian and Hungarian full-scale experiments have shown the possibility of appreciably accelerating the malleablizing process by hardening between 920–1000° C before malleablizing.—P. K.

The Influence of Chromium and Boron on the Properties of Malleable Cast Iron. E. Chapo. (*Kohászati Lapok*, 1954, **9**, Feb., 25–30). The stabilizing effect of each 0·01% Cr on the carbides in malleable cast iron can be balanced by an increase of 5° C in tempering temperature, by 10% in tempering time, or by 0·05% silicon. To avoid distortion and separation of graphite the upper limit of tempering temperature 950° C and increase of Si content 0·1% max. must not be exceeded. Boron furthers the stability of carbides and simultaneously the nucleation of graphite. It increases the time of the decomposition of carbides to a certain extent and essentially decreases the time of decomposition of pearlite. Addition of 0·003–0·005% B to a malleable cast iron of 0·08–0·1% Cr content gave a satisfactory structure.—P. K.

Castings of Grey Iron and Malleable Iron into Chills. F. Naumann. (*Kohászati Lapok*, 1955, **10**, Nov., 269–274). A review is given of chill castings, with many examples, as well as of the composition and construction of chills. The following chill composition is suggested: 3·2–3·7% C, 1·6–2·5% Si, 0·5–0·8% Mn, 0·25% P max., 0·12% S max. The thickness of the chill wall should be 1½–2 times of that of casting.

Copper Alloyed Grey Cast Iron. N. Hajtó and F. Varga. (*Kohászati Lapok*, 1952, **7**, June, *Öntöde*, 121–129). Laboratory and full scale experiments with copper addition to molten grey iron in the range 0·5–10% resulted in the following observations: (1) An increasing Si content decreases the solubility of Cu in iron, the ultimate tensile strength, compression strength and Vickers hardness. (2) The above-mentioned mechanical properties improve with increasing Cu content up to 2–2·5% above which the values slowly diminish.—P. K.

White Iron with Molybdenum Has Improved Wear Resistance (*Materials in Design Engineering*, 1957, **46**, Aug., 144–145). Climax 321, a Ni–Cr–Mo steel, is described. Hardness and abrasion resistance are given.

Cast Irons Alloyed with Manganese, Aluminium, Boron, Titanium and Magnesium. N. Hajtó. (*Kohászati Lapok*, 1954, **9**, Mar. 49–58). Experimental casts were melted in a 1 kg Tamman furnace with various Mn, Si, Al, and Mg contents. Bars of 10 and 20 mm dia. were cast in sand moulds and examined metallographically in cast and heat treated conditions. According to the alloy content and heat treatment, lamellar or spheroidal graphite was obtained in a pearlitic, ferritic, martensitic, bainitic or austenitic matrix. The author refers to experiences in other countries on cast irons alloyed with B and Ti. The use of all these cast irons depends on their mechanical, magnetic and electrical properties as well as on their wear resistance and resistance to chemical attack, but these properties are yet to be examined.—P. K.

Construction of Grey Iron and Steel Casting Machine Elements in Regard to Foundry Technique. G. Jándy. (*Kohászati Lapok*, 1955, **10**, March, 47–54). The main principles for adequate construction of grey iron and steel casting machine elements are given, with examples.—P. K.

Preparation of Nodular Graphite Cast Iron from the Vlahita Cast Iron Quality F X 1 STAS 882–49. D. Voiculescu. (*Met. Constr. Masini*, 1957, **9**, (2), 36–46). [In Rumanian]. The article is a full description of the procedure of the "1st May" plant. It contains a full and detailed description of the necessary installation of the raw materials used, of the technology and technical details and a description of the qualities of the nodular cast iron so obtained.—L. H.

Study on Pearlite Nodular Graphite Cast Iron. I, II. S. Tsutsui. (*Tetsu to Hagane*, 1957, **43**, Mar., 253–254; 254–256). [In Japanese]. The influences of Cr, Mo, V, W, Cu, Mn and Sn on several nodular graphite iron structures are considered.

New Russian Achievements in the Production of Spheroidal Cast Iron. J. Piaskowski. (*Przeglad Odlewnictwa*, 1955, Oct., 300–312). [In Polish]. The scientific basis for the formation of spheroidal cast iron, investigations into production processes, effects of additions of Mg and Fe–Si, industrial scale production and improvements, heat treatment, experiment in plastic processing, nitridation, mechanical and casting properties and the uses of spheroidal cast iron are discussed. Designs, graphs and tables of numerical data are given. (42 references).—P. W.

Application of Spheroidal Cast Iron as Material Resistant to Abrasion. M. Pachowski. (*Przeglad Odlewnictwa*, 1956, Jan., 10–12). [In Polish]. A description is given of comparative working tests of various cast iron and steel mill hammers. The spheroidal C.I. hammers were shown to have about 20% longer working life than those of Mn steel and about 2½ times and 4½ times as long as those of carbon steel and cast iron (with flaky graphitic structure) respectively, thus demonstrating the exceptionally high resistance of spheroidal cast iron to abrasion. The author considers the spheroidal cast iron to be a material particularly suitable for mill hammers.

Nodular Graphite Cast Iron Used in Railway Engines. A. Chisu. (*Met. Constr. Masini*, 1957, **3**, 16–21). [In Rumanian]. It has been established that nodular graphite cast iron Nr. 3 has a higher thermal stability than the other two qualities in general use and especially higher than grey iron. The whole process of production is described in detail with tabulation of physical and chemical properties.—L. H.

Investigations with a View to Replacing the Use of Ductile Cast Iron for Agricultural Machinery Components with Nodular Graphite Cast Iron. D. Rasecv and C. Teodorescu. (*Met. Constr. Masini*, 1956, **8**, (6), 41–51). Nodular graphitic cast iron shows some mechanical characteristics equal or superior to ferritic and pearlitic iron, and can be used for casting agricultural machinery components. By using this indigenous material the costs of production have been greatly reduced especially in its heat treatment. This cast iron can be economically produced in small units in the factories themselves and poured into dies or moulds on the spot.—L. H.

Malleable Production at the Nacton Foundry of Ransomes, Sims & Jeffries, Ltd. H. Q. Wincer. (*Foundry Trade J.*, 1957, **103**, Oct. 10, 423–431). Progress since 1951 is recorded. The design and installation of a gas-fired annealing oven and the setting up of a control system, the estimation of S : Mn ratio by appearance of the fracture troubles with cracking, a new bogie-type oven and its operation, annealing pot packing and unpacking and some products are all described.

Some Steps in the Development of High Duty Malleable Cast Iron. B. Thyberg. (*24th International Foundry Congress Papers*, 1957, 374–399). Development work by the Husqvarna concern is described. Mn and Cu additions and special heat treatment converted a ferritic to a pearlitic malleable grade producing material of ultimate tensile strength 62–67 kg/mm², elongation 5–8% and Brinell hardness 195–230. "Inverse greyness" is also discussed and methods for preventing it are given. Hardening of malleable iron is considered.

Regarding the Technique of Melting Malleable Cast Iron and the Prospects of its Development in Rumania. L. Apa (*Met. Constr. Masini*, 1956, **8**, (12), 47–54). [In Rumanian]. After consideration of the special local conditions the report advises that only the continuous process should be used, either in a blast furnace, or in a combined blast and electric furnace. Since blast-furnace melting requires a high quality coke, it is recommended that blast furnace and rotary furnace, or blast furnace and acid electric furnace should be made use of. Neither of these methods was as yet applied at the time of this study.—L. H.

U.S.S.R. Advances in Malleable Cast Iron Production. J. Raczka. (*Przeglad Odlewnictwa*, 1956, **6**, Oct., 307–315). [In Polish]. The author discusses the development of malleable cast iron production in Russia from the beginning of the 20th century to the present day. Based on recent publications in the U.S.S.R. a theoretical basis for graphitization of cast iron is given. He describes in detail with diagrams the most modern methods of production of pearlitic malleable cast iron of high quality, methods of reducing carbon contents in cast iron, different methods of melting, including duplexing, and different methods for shortening heating time.

Development of a Method of Hardening Malleable Iron Catings in a Swedish Foundry. H. Weber. (*Gjuteriet*, 1957, **47**, Aug., 166–172). [In German]. Method of production, raw materials and annealing are outlined. The hardening process is then described and abrasion resistance, impact strength and weldability are noted.

Carbon Steel Casting in Green Sand. E. Janicki. (*Przeglad Odlewnictwa*, 1956, **6**, July, 194–202). [In Polish]. Problems connected with the preparation of the moulds are discussed. Special attention is directed to some of the important proper-

ties of the green sand mould: permeability, fluidity, strength, absorption and plasticity. The dependence on the water contents of the sand of the properties of castings is considered.

Metallurgical Aspects of Hot Tearing in Cast Steel. K. Beckius. (*24th International Foundry Congress Papers*, 1957, 245–285). An apparatus on the tension spring principle was used to study hot tearing, the restraining load being removed at intervals after pouring and temperatures being observed. The dependence of hot tear susceptibility on pouring temperature and on C, Si, Mn, P, and S was worked out and mechanism is considered. Comparison is made with practical conditions.

Casting Large Steel Parts from Mixed Steel. G. A. Ravich and G. V. Moroz'ko. (*Liteinoe Proizvodstvo*, 1957, (1), 1–3). [In Russian]. An account is given of the production of large steel castings from mixtures of Bessemer and electric-furnace steel. The ratios used in preliminary tests were 2 : 3, 1 : 1, 3 : 2, 1 : 3 and 7 : 13, and the mixing was carried out in the ladle. The mechanical properties of the mixed-steel castings were determined at room and various sub-zero temperatures and compared with those of the component steels. The mixed steel was successfully used for large (13-t and 23-t) castings. The gating systems used are considered and chemical and mechanical properties of specimens from different parts of the castings are tabulated.—S. K.

Graphitized Steel as a Material for Casting. P. P. Berg and S. P. Nestertsev. (*Liteinoe Proizvodstvo*, 1956, (12), 25–27). [In Russian]. Investigations and works experiments on casting steel with 1·0–1·7% C are described. In the investigation the C content was gradually increased over a range, the Si, Mn, Cr and Cu contents also being varied. The effects of these changes of composition on the structure and properties after heat treatment and also the effects of inoculation with Al, Fe–Si, Fe–V, Fe–Ti, Si–Ca, Si–Zr and Mg were studied, special specimens being used for the latter work. The results, confirmed by production experience, indicate the suitability of graphitized steel for casting a wide variety of objects, including rolls.—S. K.

The Casting of Carbon Steels with Boron Additions. A. E. Gol'dstein, L. L. Pyatakova and O. D. Zhizhakina. (*Vestnik Mashinostroenniya*, 1956, **36**, (7), 23–27). [In Russian]. It is known that a small addition of B to steels containing 0·2% C and 1·6% Mn is equivalent to 0·85% Mn plus 1·4% Ni. or 0·35% Mo etc. The boron phase of such alloys is fully described as well as the experiments made with specimens containing between 0·2% and 0·3% B. Tractor driving wheels with boron steels after suitable hardening and tempering have shown superior mechanical qualities to wheels mass-produced from ordinary steels.—L. H.

Refractory Chills. Experiments Carried out at Carntyne Steel Castings, Ltd. A. Scott. (*Foundry Trade J.*, 1957, **103**, Oct. 3, 407–409). Avoiding hot tearing by physical and thermal methods is described, especially by the use of chills.

Mass Effect of Alloy Steel Castings. I. A. Suzuki. (*Tetsu to Hagane*, 1957, **43**, Mar., 271–273). [In Japanese]. Results are reported for carbon steel, two low-Mn steels and 13% Cr steel (analyses given), inormalized and tempered, or homogenized, normalized and tempered. Specimens from five different positions in large castings show the variations in mechanical and physical properties and composition.

Automatic Tempering of Moulding Sand. H. W. Dietert, A. Graham and R. Dietert. (*24th International Foundry Congress Papers*, 1957, (2), 429–444). The advantages of sand of constant humidity and of automatic tempering are described. The open and closed pan weighing tests for moisture are evaluated. Sand cooling is important and wide temperature variations make uniform tempering more difficult.

Green Moulding Sands for Heavy Castings. T. Rzepa and Z. Wertz. (*Przeglad Odlewnictwa*, 1956, **6**, July, 202–208). [In Polish]. The advantages of using green sand mixtures are discussed. Data and properties of different Polish sands are tabulated and methods of preparation of green moulding sands for heavy castings are given. Examples of the composition of synthetic and natural green sand mixtures are shown. The Polish foundries lack experience in this type of work and the need for development is emphasized.

Some Steelfoundry Mould and Core-Sand Mixes. R. M. Chapman. (*Foundry Trade J.*, 1957, **103**, Oct. 3, 395–398). Cold-setting core binders with partial substitution of Wyoming bentonite by kaolinite and the use of resin core-binders are discussed.

The Influence of the Clay Binder on Green Properties of Foundry Sands. W. Patterson and D. Boenisch. (*24th International Foundry Congress Papers*, 1957, (2), 401–427). The relation of swelling capacity of clays to moisture sensitivity is discussed and the effects of sand preparation are considered in detail. A relationship is derived for time of milling, initial moisture and size of charge. Milling effects are also investigated.

Zircon Sand—A Valuable Foundry Tool. Carpenter Bros. Inc. (*Castings*, 1957, **3**, June, 7, 9). Mixes are suggested.

How to Avoid Sand Segregation. American Foundryman's Society Committee 8-F and Grading and Fineness Committee, National Industrial Sand Association. (*Mod. Castings*, 1957, **32**, Sept., 50–51, 56). Segregation occurs whenever sand is transported, most extensively on placing in and removing from storage. Sieving experiments are quoted and trials with dyed sand are referred to. Methods of minimizing the phenomenon are given.

Mechanization of the Drying and Transportation of Sand. L. N. Sosnin. (*Liteinoe Proizvodstvo*, 1957, (2), 30). [In Russian]. An account is given of a mechanized assembly for treating foundry sands, consisting of two $4 \times 4{\cdot}5 \times 2{\cdot}3$ m sand blowing chambers, a rotary drying kiln, two wet filters, a settling tank and ventilating arrangements.—S. K.

How to Use Olivine Sand. W. A. Snyder. (*Foundry*, 1957, **85**, Sept., 100–105). Moulds and cores and ladle linings and washes are discussed. Casting of Mn-steel and carbon steel parts are described and suitable mixtures of olivine sands are given.

Automatisation of Filling Moulding Sand Bunkers. R. Chudzikiewicz. (*Przeglad Odlewnictwa*, 1956, **6**, Aug., 225–229). [In Polish]. A survey of methods of filling moulding sand bunkers is given. Different methods of indicating the level in the bunkers are described. The automatic systems introduced in Russia in 1950 and 1952 are described and critically evaluated.

The Use of Synthetic Sands in Medium Castings. E. Reszel. (*Przeglad Odlewnictwa*, 1956, **6**, July, 208–215). [In Polish]. The advantages of using synthetic sand moulds are discussed. The composition of synthetic sand mixtures used for medium castings and their physical properties are given. The technology of preparations of synthetic sand moulds are outlined. Defects in the castings and their elimination are described.

Conditions for the Automation of Moulding Sand Preparation. Z. Izykowski. (*Przeglad Odlewnictwa*, 1956, **6**, June, 175–178). [In Polish]. The conditions and directions of automation of moulding sand preparation are discussed. It is suggested that a preliminary mixing of the sand would be an advantage. The author describes experiments conducted to determine the degree of mixing in the preliminary process.

Industrial Methods for Reclaiming "Burnt" Moulding Sand. W. Chabowski and Z. Wertz. (*Przeglad Odlewnictwa*, 1955, Dec., 363–370). [In Polish]. The article is a review of the problem which in Poland is still in its experimental stage. The composition and structure of "burnt" sands, general principles, schemes and examples of industrial installations for reclaiming by dry and wet procedures, processes and separations involved are discussed, and the properties of moulding sands and core sands, made up with and without reclaimed material, are compared. Sketches and tables of numerical data are included.

Laboratory Radiation Dryer for Drying Sand Samples. R. Karpinski. (*Przeglad Odlewnictwa*, 1956, **6**, July, 215–216). [In Polish]. The author gives a description with diagrams of a laboratory dryer which has been in use for 5 years, the radiators were replaced twice only. The good points of the design are: simplicity and low cost of construction, and use, easy replacements. The bad points are: inaccuracy above 110° C (which in practice is minute) and the danger of electric shock.

Preparation of Moulds and Patterns from Mixtures with Water Glass as Binder, Hardened with Carbon Dioxide. C. Stefanescu and I. Gentiu. (*Met. Constr. Masini*, 1957, **9**, (6), 11–24). [In Rumanian]. This new process is based on the property of the alkaline silicates such as sodium silicate, of decomposing in the presence of water and CO_2 to form SiO_2, which changes into a hydrogel. This hydrogel becomes a binder in an acid medium when it forms silica gel. In a neutral or alkaline medium the hydrogel is in powder form. When using sodium silicate as a binder, the various sands

constitute an acid medium, the more acid, the more quartz and the less clay they contain. This forms the basis of a complete elaboration of this process which is here described in full.—L. H.

Engineering Aspects of Core Box Design. R. L. Olson. (*24th International Foundry Congress Papers*, 1957, (2), 587–599). A special sealing method is described protecting the junction of the two halves against erosion.

Zones of Influence of Feeders. R. Namur. (*24th International Foundry Congress Papers*, 1957, 193–222). A systematic study of factors affecting feeding distance from shrinkage heads leads to 6 general rules for an efficient pouring and feeding system, and a formula for feeder diameter is given.

Exothermic Mixtures for Risers. K. Korecki and T. Welkens. (*Przeglad Odlewnictwa*, 1956, **6**, Sept., 292–300). [In Polish]. The author discusses the application in risers of exothermic sleeves. The methods and results of experiments carried out in the Foundry Research Institute in Cracow on exothermic mixtures for non-ferrous metals, spheroidal cast iron and cast steel are given. The best results are obtained with mixtures with an aluminothermic reaction. A study of effects of the filling materials and the question of the gases evolved from the exothermic sleeves are discussed.

Exothermic Feeding of Castings. K. Strauss. (*Inst. Brit. Found.*, 1956, **7**, 81–96). The uses of powder, mouldable and thermit-type materials are discussed and compared. Relative costs and comparative yields are noted in an example. The two latter processes, though factors in favour of one or the other are carefully set out, are regarded as complementary.

Multiple-Place Chill Mould with a Mechanism for Detaching Feeders. S. A. Maloi. (*Liteinoe Proizvodstvo*, 1956, (11), 13). [In Russian]. A brief description is given of a chill mould in which several small castings can be made simultaneously, the feeders being cut before they are fully hardened by a special mechanism. Considerable economies result from the adoption of the new mould.—S. K.

Use of Centrifugal Force in the Gating System. V. P. Antonov. (*Liteinoe Proizvodstvo*, 1956, (11), 7–9). [In Russian]. A gating system is described in which the separation of slag from metal is promoted by centrifugal forces due to flow through a curved channel. Examples of castings produced are illustrated.—S. K.

The Air Compression Moulding Machine as a Foundry Aid. A. J. Zuithoff and J. P. Zondervan. (*Metalen*, 1957, **12**, Aug. 15, 280–288). [In Dutch]. The authors describe at length the experience gained with an experimental moulding machine using a membrane in conjunction with compressed air constructed at the Foundry Laboratory of the Delft Technical University. Data are given of the resulting sand hardness and the influence of time and pressure exerted. There is also a comparison between conventional squeezing/jolting methods and the new one. (10 references).—F. R. H.

"Proper" Coal Dust in Moulding Sands. S. Jarzebski. (*Przeglad Odlewnictwa*, 1956, **6**, Sept., 286–291). The importance of pulverized coal in moulding sands is discussed. Coal dusts from 15 mines of the type 31/35 of the Polish Mining Standard PN/G-97002 were tested. The author describes and illustrates with graphs the difference in tensile strength and permeability of moulding sands with different contents of the various coal dusts and at different temperatures. For "proper" coal dust the most suitable are vitrain and clarain of the type 34/35 and a concentrated form is recommended, and its advantages described.

New Methods of Making Exact Moulds and Cores. A. M. Lyass and P. A. Borsuk. (*Liteinoe Proizvodstvo*, 1956, (12), 1–5). [In Russian]. Accumulated experience and results of investigations on the use of water-glass based mould and core mixtures (the CO_2 method) are presented and discussed, mainly from the aspect of casting precision. The influence of mixture composition and CO_2-treatment conditions are considered, and the technology of mould and core preparation discussed, with special reference to the use of ordinary mould mixtures faced with the water-glass base mixture and to the use of the latter for making shell moulds and for cores. Shell-mould type cores and the use of shell mould inserts for parts of the casting needing greater accuracy are also discussed.—S. K.

Rapid Preparation of Coated Mould Mixture. A. I. Korotkov. (*Liteinoe Proizvodstvo*, 1957, (2), 4–5). [In Russian]. Microscopical observations on shell-mould mixtures, prepared under various conditions are reported on the basis of which a rapid preparation method was developed. This method secures the even coating of sand grains with the binder.—S. K.

Metallurgical Problems Encountered with 12–15% Cr-Steel Castings. I. E. Zingg and T. Geiger. (*Schweiz. Arch. Wiss. Tech.*, 1957, **23**, March, 71–78). The properties and application of high-Cr steels are discussed in relation to their chemical composition and structure. Variations in properties with heat treatment are then dealt with. This is followed by a short survey of methods for producing Cr steels with low C, P, S, H, O and N content. **II.** (April, 121–127). Experiments are described regarding transformations in the Ac_1 region. Dilatometric, thermometric and X-ray methods are used, supplemented by micrographs. The α–γ transformation depends on the nickel and carbon contents of the steel.—R. P.

Steel Castings for Colliery and Mining Equipment. (*Brit. Steel Found. Assoc.* 1957, pamphlet, pp. 16). An illustrated review.

Material Saving by Using Exothermic Feeder Heads. I. Gera. (*Kohászati Lapok*, 1955, **10**, March, 66–67). The author refers to Hungarian experiments on the use of exothermic feeder heads in steel foundries.—P. K.

Surface Area of Sand. R. E. Morey. (*Foundry*, 1957, **85**, Aug., 100–101). Interpretation of sieve analyses is described.

Method to Determine the Shape of a Moulding Sand Grain. II. The Effect of the Shape of Foundry Sand on Permeability. J. Kashima. (*Rep. Castings Res. Lab. Waseda Univ.*, 1956, Oct., 25–27). [In English]. Results from two types of foundry sand and glass grains with various binders show that the permeability of sand moulds with 4% of binder is affected much more by the size than the shape of the grains. It is assumed that, if it is possible to reduce the binder content to zero and obtain a permeability value below 150, the grain shape index can be determined by Davis' method.—K. E. J.

The Effect on Pattern Making of New Foundry Methods. H. Klotz. (*Giessereitechn.*, 1957, **3**, June, 130–132). A brief description is given of the CO_2-waterglass method, the lost wax precision casting method, the Croning matrix mould process, and chill casting of ferrous metals. The demands each of these makes upon the pattern maker are briefly sketched.—L. J. L.

A Method for Calculating Material Standards for Wood Patterns. I. Szalkai. (*Kohászati Lapok*, 1955, **10**, *Ontöde*, Aug., 182–184). A method is given for calculating material standards for wood patterns. It is based on the degree of complexity of the casting and on the kinds of wood available in Hungary.—P. K.

The Use of Core Supports in Iron Foundries. (*Fonderie*, 1957, Feb., 90–95). The different types of steel core supports that can be used are illustrated and described in detail. The methods of using the supports are then briefly discussed.

The Effect of the Rate of Pouring on the Quality of the Casting. W. Göschel. (*Giessereitechn.*, 1957, **3**, June, 734–136). It is concluded that the chances of obtaining a perfect casting are greatest if pouring time is kept to a minimum, the risers are carried up, and the size of the pouring basin is adapted to the pouring rate.—L. J. L.

The Substance and Practice of Rapid Casting. M. Csiszár. (*Kohászati Lapok*, 1953, **8**, *Ontöde*, Sept., 189–196). The author describes a new rapid casting method, without hot topping, for grey iron, developed in Hungary. A graphical method is given for determining the optimum casting time from the weight of casting. Reference is made to the advantages and difficulties of this method.—P. K.

Calculating Gating Systems in Iron Foundries. S. Vékony. (*Kohászati Lapok*, 1955, **10**, March, 63–65). The author gives a method for calculating gating systems in iron foundries, based on the quantity of molten metal poured in the mould per sec, and on the principles of free fall and turbulence.

Steel Foundry Speeds Coremaking. E. Beurig and D. McGowan. (*Mod. Castings*, 1957, **32**, Aug., 52–53). A corn sugar binder containing a catalyst has been developed. The catalyst consists of 6% ammonium sulphate which converts the sugar to a resinous substance during baking.

A Novel Core Moulding Machine. E. Knipp. (*Giesserei*, 1957, **44**, Apr. 25, 267–268). A brief article in which the manufacture of cores from moulding sand, CO_2-sand, oil-sand and cement-sand is described. The core moulding machine, which is capable of making up to 5 cores simultaneously is then described and illustrated.—R. J. W.

The CO_2 Method of Production of Medium-Sized Iron Castings. E. Sabel. (*Gjuteriet*, 1957, **47**, June, 99–102). Sand from a local sand pit is used once and disposed of. Water glass is used at a minimum of 8% and of low sp. gr. on account of the dust content. Core walls are thinner than normal. Porosity is important to let out steam formed. CO_2 introduction takes 15 sec. per inlet and 2·1% is used by wt. Water should be avoided in blacking and spirit or resin bases are preferable. The CO_2 method eliminates mould and core drying but costs are otherwise much the same as for oil-sand.—R. K. E.

Is CO_2 Necessary? C. E. Wulff. (*Mod. Castings*, 1957, **32**, Aug., 28–29). It is shown that dry N_2 or dry compressed air are superior to CO_2 for hardening small cores. The advantages of sealed mullers are noted.

The Air Setting Process. D. R. Chester and W. E. Mahoney. (*Foundry*, 1957, **85**, Aug., 110–113). The use of a drying oil binder with driers for large core making is outlined.

The Production and Use of Synthetic Moulding Sand. K. Szápesi. (*Kohászati Lapok*, 1952, **7**, Aug., *Ontöde*, 189–192). The raw materials, production, composition, characteristics and use of synthetic moulding- and core-sands are reported.

Experiences with the Full Scale Introduction of Synthetic Moulding Sands. A. Toth. (*Kohászati Lapok*, 1952, **7**, July, *Ontöde*, 154–159). Hungarian experiments on laboratory and full scale production of synthetic moulding sands are reported, the proper characteristics of these sands specified, the appropriate moulding techniques and suitable casting methods described and the advantages and disadvantages of the use of synthetic sands considered.—P. K.

Mold Treatment: The Key to Quality Castings. H. Chappie. (*Iron Age*, 1957, **180**, Aug. 15, 98–101). Experience and experiments are cited in recommending the best treatment of sand moulds prior to casting. Tests indicated that moulds with an air-drying time (prior to oven drying) of under 10 h gave the best castings.—D. L. C. P.

The Use of Exothermic Cores in Steel Foundries. T. Budinsky. (*Kohászati Lapok*, 1952, **7**, Oct., *Ontöde*, 224–228). Experiments with the exothermic heating of feeding heads of steel castings are described. An average increase of 15–20% in the yield was obtained as a result of these experiments.

Working with Waterglass—Containing Moulding Sand without Carbon Dioxide Hardening for Iron and Steel Casting. A. Gebauer and O. Gerstmann. (*Giessereitechn.*, 1957, **3**, Apr., 73–77). Mixtures are described in which waterglass is used as a binder but which do not require CO_2 for hardening. The advantage of this is that patterns can be removed from the mould while it is still in the plastic state.—L. J. L.

Theoretical and Practical Problems in Bentonite Research. H. E. Schwiete. (*Giesserei*, 1957, **44**, Mar. 28, 165–174). The chemical composition and structure of clay minerals is described and illustrated. These minerals fall into three main groups, viz., the kaolinites, the illites and the montmorillonites. The swelling and cation-exchange properties of these different groups are discussed. The different methods available for investigating bentonites are chemical analysis, optical microscopy (including phase contrast), electron microscopy, X-rays and thermochemical techniques. The methods of X-ray analysis, thermochemical and ceramic methods are the described in considerable detail.—R. J. W.

Bonding Characteristics of Rajasthan Bentonite. B. V. Somayajulu and B. R. Nijhawan. (*J. Sci. Indust. Res.*, 1957, **16A**, June, 256–268). Mixtures with Rajmahal sand suitable for steel castings in dried and green conditions were found. Optimum strength, permeability and shatter index were obtained with 5% bentonite and 2% moisture for green and 5% for dry sand moulding.

The Influence of Bentonite Quality and Specific Surface of the Sand Grains on the Compressive Strength of Bentonite-Sand Mixtures. J. Barna and Z. Juhász. (*Kohászati Lapok*, 1953, **8**, Nov., 226–233). The authors worked out a new theory for bonding by bentonites. They found that the larger the specific surface of the sand grains the less is the compressive strength of the bentonite-sand mixture. A method is given for measuring the specific surface.—P. K.

The Croning Method of Mould Casting in the Steel Foundries of the East German Republic. H. Woykoss. (*Giessereitechn.*, 1957, **3**, June, 123–126). Progress made in the application of the method is reviewed. Some operating experience has been obtained, but no data are yet available on the economics of the method.—L. J. L.

Inorganic Binders for Moulds, Especially Sodium Silicate, Prepared for the CO_2 Process. H. Miyasaka. (*Rep. Castings Res. Lab. Waseda Univ.*, 1956, Oct., 33–40). [In English]. From tests on locally-prepared water-glass and "Foseco CO_2 Set," the optimum properties required for the CO_2 process are deduced. The permeability of the CO_2-treated mould does not change markedly with variations in water-glass content or gassing time. The max. strength is developed within 20–30 sec. of gassing. Organic binders in amounts up to 1% improve the green strength of CO_2 moulds. Gas evolution is less than from moulds made with phenolic resins on linseed oil.—K. E. J.

Application of Sodium Silicates for Bonding Sands. F. W. Nield and D. Epstein. (*Inst. Brit. Found. J.*, 1957, **50**, Sept., 457–465). Silicates with $SiO_2 : Na_2O$ ratios of 2, 2·5, 2·9 and 3·3 were tested with CO_2 hardening. Compression strength and gassing time were measured and cured and uncured specimens were heated to 1200° C and compression strength determined. Explanations are attempted of silicate composition and effect.

A Contribution to the Theory of Chemically Hardened Foundry Sands. (CO_2 Process). L. Petrżela. (*24th International Foundry Congress Papers*, 1957, (2), 467–495). The theoretical amount of CO_2 is 0·3% and in practice not more than 1% should be required. Four grades of silicate were used and strength after hardening, after drying, and abrasion resistance were shown to depend upon amount and type of binder and on moisture content. Heat properties are related to the back reaction of hydrated silica with sodium carbonate at 200–500°. Thermal expansion is small and above 400° shrinkage takes place. Surface quality of castings is considered.

Rx for Swollen Grey Iron Castings. J. F. Wallace and E. B. Evans. (*Mod. Castings*, 1957, **32**, Sept., 47–49). Sand additives for preventing mould wall movement are discussed. Reduction and elimination of casting dilation are tabulated and effects of sand and graphitic carbon are considered. (18 references).

Core Blowing. M. Burfoot. (*Inst. Brit. Found.*, 1956, **7**, 35–47). Selection and operation, sand properties, auxiliary equipment, and examples of core production are described.

Properties of Moulding Materials at Elevated Temperatures. L. Petrżela. (*Przeglad Odlewnictwa*, 1957, **7**, March, 65–76). A survey of literature, methods and apparatus used in research is given. The author describes in detail experiments conducted on the thermal expansion, compressive strength and basic properties of different moulding materials in dry and wet conditions. The formation of scabs and other deformations are discussed. Results are tabulated.

Water-Soluble Cellulose Ethers as Binders for Foundry Purposes. R. Morén. (*Gjuteriet*, 1957, **47**, Aug., 157–165; *Eng. Digest*, 1957, **17**, Sept., 399–401). [In English]. The use of ethyl-hydroxyethylcellulose with or without melamine, linseed oil or starch and of other cellulose ethers is described and many curves and tables of strength and permeability are given.

New Core Sand Binders. J. Buciewicz and T. Rzepa. (*Przeglad Odlewnictwa*, 1955, Dec., 358–363). [In Polish]. A study has been made of the application of urea-formaldehyde resin "121" and oil "ST" (unsaturated vegetable oils, 30–35%, abietic and dihydroabietic acids, 60–65%, water, 5%) as binders for core sands instead of the linseed oil normally used in Poland for this purpose. Conditions for the application of these substances in core sands, and physical and technological properties of the resulting sands and cores are discussed and numerical data tabulated.

Metal Penetration into Sand Cores. K. Fursund. (*24th International Foundry Congress Papers*, 1957, 287–307). A method of testing 44 cores simultaneously was used, with 4 different mixtures. Temperature and time readings were made. No differences were found when casting temperature was 10–40° C above liquidus temperature. Pressure, above a minimum, produces proportionate penetration. Where organic material is present, C may dissolve and a lower pressure will serve.

Casting of Iron Alloys in Permanent Moulds. Part I. J. Kuszewski. (*Przeglad Odlewnictwa*, 1956, Feb., 39–45). [In Polish]. In the present paper, the first of two, the principles of production of chill moulds and the technology of casting in them are reviewed on the basis of data from the literature. **Part II.** (March, 65–71). The properties of castings made in chill moulds are discussed on the basis of data from the literature, and an account is given of experi-

ments with this method of casting. The economic aspect is considered. (14 references).

The Design of Steel Castings with Regard to the Laws of Solidification. (*Usine Nouvelle*, 1957, **13**, Sept. 12, 95, 97, 98). Choice of thickness, avoidance of hot spots and the use of grooves and recesses, allowances in closed profiles for a certain amount of deformation, providing for directional solidification by a degree of asymmetry and various methods of facilitating casting are discussed.

The Pouring Time of Sand Castings. J. S. Abcouwer. (*24th International Foundry Congress Papers*, 1957, 223–243). A discussion of factors influencing pouring time where heat loss gives the upper limit and the danger of erosion gives the lower limit leads to an equation containing a condition of superheat and a condition of heat loss during mould filling. Applications are given.

Casting of a 5·5 ton Hydraulic Press Plunger in Spheroidal Cast Iron. A. Bargiel. (*Przeglad Odlewnictwa*, 1956, **6**, Aug., 238–241). [In Polish]. The author gives a detailed description with diagrams and photographs of an attempt to obtain large castings in spheroidal cast iron. The experience gained helped to cast a more complicated plunger of 9 t which had to withstand a pressure of 2500 t.

Australian Methods of Producing Special Pipes. G. J. Benson. (*Inst. Brit. Found.*, 1956, **7**, 1–14). Methods of producing cast iron pipes are described by frame and strickle and shell moulding, mould production, casting and fettling and production of special tackle are discussed.

Casting Internal-Combustion Engine Heads from Magnesium Cast Iron. M. I. Rotenberg and V. I. Soldatenko. (*Liteinoe Proizvodstvo*, 1956, (11), 23–25). [In Russian]. Details are given of the use of Mg–inoculated iron for casting cylinder heads. The quality of the castings is discussed and the mechanical properties obtained with irons of various compositions are compared.—S. K.

The Use of Cast Iron for Car Wheels. K. Hess. (*Przeglad Odlewnictwa*, 1956, **6**, Sept., 268–278). [In Polish]. The idea of the application of inoculated cast iron for car wheels was based on hints in the literature and on industrial trials, with the resulting production of the high quality cast iron ZIM 38. The author gives theoretical calculations of cast iron wheels pressing on flat and convex rails, and diagrams of interrelations of load, size of wheel and rail and maximum speed of motion and iron quality against pressure exerted on the rail. The wheels of a mining car and of a crane were thoroughly investigated and the results are shown. The two walled design without ribs and with 3 holes in the shield was found most suitable and was constructed of ZIM 26. The method of production of this design of wheel is described.

U.K.'s Largest Roll Housing. (*Foundry Trade J.*, 1957, 103, Aug. 29, 259–261). An illustrated account of the casting of a 164-t mill housing is given.

Shell Moulded Crankshafts Replace Forgings in Outboard Motors. J. Sutherland, F. T. Chesnut and E. Bremer. (*Foundry*, 1957, **85**, Sept., 106–111). An illustrated account, with a schematic plan, of the process at Milwaukee.

Contribution to Raising the Quality of Tractor Spares Cast in Indigenous Cast Iron. E. Marculescu and S. Stefanescu. (*Met. Constr. Masini*, 1957, **3**, 32–37). The whole process of production from the selection of the raw materials to the final casts, is reviewed, and attention is drawn to the errors occurring during the process. Statistics are given showing faulty castings, followed by an analysis of the defects.—L. H.

Casting of Chilled Rolls in Moulds with Plastering. V. S. Krasovitskii. (*Stal'*, 1957, (9), 855–857).

Attempts at Centrifugal Casting of Spheroidal Cast Iron Liners. M. Curzytek. (*Przeglad Odlewnictwa*, 1956, **6**, Dec., 368–372). [In Polish]. The author describes the positive and negative qualities of spheroidal cast iron, and compares the advantages of centrifugal casting with the static process. The results of attempts at spheroidal casting made by the author are described and tabulated. The mechanical properties of the liners obtained from 10 different spheroidal castings are tabulated.

Automation of the Production of Castings by the Lost-Wax Process. I. V. Efimov. (*Liteinoe Proizvodstvo*, 1957, (2), 6–8). [In Russian]. From an analysis of the performance of an existing installation for lost-wax process casting an automatic variant has been designed by the NIIAVTOPROM organization. In the present article, details are given of this installation which consists of the following main parts: an assembly for melting the modelling composition, storage tank, paste preparation tank with stirrers and a collector, extrusion device, table with press moulds and a pumping station with three pumps. The installation can produce over 1440 model sections per shift, the productivity of the paste preparation device being 60 kg/hr.—S. K.

Production of Shell Moulds. R. Najberg. (*Przeglad Odlewnictwa*, 1956, March, 78–79). [In Polish]. An installation for the production of shell moulds for an output of 250 complete shell moulds per shift, is given. The team consists of two workers.

The Technology of Shell Moulding. J. Harpula and Z. Wertz. (*Przeglad Odlewnictwa*, 1957, **7**, Feb., 29–35). [In Polish]. The authors discuss the technology of shell moulding and its range of application and they describe methods of obtaining shells of higher strength. Details of shell moulds of the Polish made equipment ÚS–03 and of core production are given.

Some Special Features in the Production of Shell Moulds. I. P. Fominykh. (*Liteinoe Proizvodstvo*, 1957, (2), 28–29). [In Russian]. The following aspects of shell moulding are considered: composition of mixtures, their gas-permeability and methods of measuring it, gas removal and paints.—S. K.

The Sticking Together of Shell Half-Moulds. I. E. Shub, N. V. Shorygina and P. I. Kantor. (*Liteinoe Proizvodstvo*, 1956, (11), 2–5). [In Russian]. Materials, devices and techniques for sticking together the parts of shell moulds are described and compared. Special attention is given to the selection of adhesives.—S. K.

New Variation of Mould Binding and Core Binding with Water-Glass. L. Hajdu and E. Kovács. (*Kohászati Lapok*, 1953, **8**, Nov., 243–244). A comprehensive review is given of the use of water-glass for efficient mould and core binding. Suggestions are made for satisfactory mould finishing for iron and steel castings.—P. K.

The Technique of Core Binding with Waterglass. J. Szekeres. (*Kohászati Lapok*, 1953, **8**, March, *Öntöde*, 49–56). A Czecho-Slovak method is reported and the necessary equipment described for core binding with waterglass and CO_2.—P. K.

The Use of Special Synthetic Resins in Foundries. E. Balocco. (*Fonderia Ital.*, 1957, **6**, May, 209–214). [In Italian]. The author reviews the various types of synthetic resins available for foundry work and discusses their merits. The life of synthetic cores and their cost is compared to that of metal cores. It is claimed that the use of synthetic resins can lead to considerable economy.—M. D. J. B.

Silicones and Their Use in the Foundry. I. Lipovecz. (*Kohászati Lapok*, 1954, **9**, March 58–62; April 84–88). Reference is made to the chemical composition and production of silicones as well as to their use, especially in precision steel casting.—P. K.

Pneumatic Conveying of Used Core Mixture. V. E. Taruntaev. (*Liteĭnoe Proizvodstvo*, 1956, (8), 15). [In Russian]. A brief account is given of a simple pneumatic system successfully used at the Lyubokhonskiĭ Iron Foundries for conveying used core mixture to a point 50 m away and at a relative height of 8 m.—S. K.

Gas Pressure in the Mould Cavity. I. M. Mutaguchi. (*Rep. Castings Res. Lab. Waseda Univ.*, 1956, Oct., 29–32). [In English]. At high temperatures the permeability number of sand moulds decreases in proportion to the viscosity of the gas passing, as corrected from the Sutherland equation. At high temperatures the mol. wt. of gas evolved from binders changes, and the permeability number increases in proportion to the mean mol. wt.—K. E. J.

A New Process for the Production of Model Plates for Machine-moulded Castings. H. Ropat. (*Giessereitechn.*, 1957, **3**, May, 103–105). The method can only be applied to divided patterns or those having one plane surface. The tools required, the production of the plates, the economics and the advantages, of the method are briefly discussed.—L. J. L.

Calculating the Time Required between Casting and Ejecting of the Casting from Metal Moulds. J. Vaculík. (*Slévárenství*, 1957, **5**, (5), 135–136). [In Czech]. The times required are calculated on the basis of the physical theory of heat transfer, and are claimed to be an improvement over the empirical methods used at present. The theory is applied to a practical case, and is shown to facilitate the more economic utilization of permanent moulds.—P. F.

Proper Construction of Iron and Steel Castings. J. Křemař. (*Kohászati Lapok*, 1952, **7**, *Öntöde*, May 97–102; June 129–

137). The main principles of proper construction of iron and steel castings are given with many examples.—P. K.

Ductile Iron Wheel Halves Cost. H. A. Peller, R. A. Sciple and F. L. Main, (*Product Eng.*, 1957, **28**, Aug., 162–163). Change from steel castings for the rear wheels of earth moving vehicles is described.

New Method of Large Fly Wheel Production. M. Caiszár. (*Kohászati Lapok*, 1953, **8**, May, *Ontöde*, 106–110). A Hungarian moulding and casting technique for large grey iron fly wheels is described.—P. K.

Centrifugal Steel Casting. I. Kovács. (*Kohászati Lapok*, 1953, **8**, June, *Ontöde*, 128–134). The author describes centrifugal steel casting experiments in Hungary and refers to the economy of this method, as well as to the quality of the experimental castings.—P. K.

Continuous Casting of Pipes. A. D. Popov. (*Liteĭnoe Proizvodstvo*, 1956, (8), 7–8). [In Russian]. The application of continuous casting to the production of cast-iron pipes is briefly described. Some causes of cracking and the testing of the pipes are considered and the suitability of the continuous casting process for the production of anti-friction piston-ring blanks is mentioned.—S. K.

Experiments on Centrifugal Steel Castings. H. Hartman and T. Kö. (*Kohászati Lapok*, 1955, **10**, *Ontöde*, Oct., 225–236). Hungarian experiments show that the centrifugal casting method does not eliminate the shrink holes, but removes them towards the centrifugal axis. The mechanical properties of centrifugal steel castings are generally better on their farthest part from the centrifugal axis, and worse on their nearest parts, than those of static castings. Least inclusions have been observed at the outside, more on the inside of centrifugal castings and most inclusions have been found in static castings. The number of revolutions of the experimental castings was 250 per min.—P. K.

Shell Moulding Experiments. J. Szekeres. (*Kohászati Lapok*, 1953, **8**, July, *Ontöde*, 150–154). The experiments were carried out to determine the most adequate sand grain size distribution, the most suitable resin content, the optimum temperature before and after resin condensations and the best release agents. Synthetic resins are also suitable for surface coating. A shell moulding machine and a core-blower are described.—P. K.

Semi-Automatic Machine for Making Cores for Shell Moulding. M. I. Rotenberg and V. I. Soldatenko. (*Liteĭnoe Proizvodstvo*, 1956, (8), 1921). [In Russian]. Details are given of a semi-automatic machine with electrical resistance heaters for hardening cores of any shape and size with open end cavities up to 20 dm^3 in total volume.—S. K.

Foundry Equipment No. 1500 Automatic Shell Core Blowing Machine. (*Machinery*, 1957, **91**, Aug. 23, 417–419).

Casting Ford Crankshafts in Shell Moulds. H. N. Bogart and H. C. Grant. (*Machinery*, 1957, **91**, Aug. 23, 432–433). A general account extracted from a paper to the Amer. Soc. Automotive Eng.

Precision Casting in Modern Production. (*Tekn. Ukeblad*, 1956, **103**, Dec. 13, 1060–1064). [In Norwegian]. Details are given of moulding procedure in the Croning and lost-wax methods, of cost reductions possible in comparison with normal sand moulding, of close tolerances attainable and of types of castings which can be produced.—G. G. K.

The Effect of Oxidation on the Surface of Molten Cast Iron. G. Nándori. (*Kohászati Lapok*, 1955, **10**, Nov., 249–260). The oxidizing effect of the atmosphere during the cooling of molten cast iron results in an oxide skin, saturated with SiO_2. This Fe–Mn silicate skin shows the so-called "surface play" or "surface patterns." The composition and shape of this skin depends on the temperature and composition of the cast iron.—P. K.

Present Problems of the Repair of Grey Iron Castings. A. Pintér. (*Kohászati Lapok*, 1953, **8**, April, *Ontöde*, 86–91). The various defects in grey iron castings and their repair, especially with metal spraying, gas- and electric-welding and metal plugs are discussed in detail—P. K.

The Avoidance of Blow Holes in Steel Castings. J. Daubner. (*Kohászati Lapok*, 1952, **7**, Sept., *Ontöde*, 209–210). The author found that the low permeability of the moulding sand for gases is the main cause of blow-holes in steel castings. Thus to avoid blow-holes in complicated steel castings a moulding sand of 180 $cm^3/cm^3/min$ permeability for gases and for minimizing them in simple steel castings a moulding sand of 150 $cm^3/cm^3/min$ permeability is suggested.—P. K.

Blow-Holes in Steel Castings. G. Szy. (*Kohászati Lapok*, 1953, **8**, Jan., 14–18). The causes of blow holes in steel castings such as those due to H_2 in steel, unsuitable moulding materials and technique, and their elimination are discussed in detail.—P. K.

Defects in a Grey Iron Steam Turbine Casting. F. Boda and Z. Hegedüs. (*Kohászati Lapok*, 1953, **8**, March, 69–70). Metallographic examination has shown that the cause of cracks in a grey iron steam turbine casting, which had worked for 35 years, was oxidation due to steam corrosion. The corrosion has started from flaws, originating from repeated thermal expansion, and progressed along the graphite veins.

Surface Porosity of Steel Castings. K. Bárzsönyi. (*Kohászati Lapok*, 1954, **9**, April, 73–78). A comprehensive review of the causes and prevention of surface porosity of steel castings. Influence of the hot top sizes and steel quality. The suggestion is made to use a green sand mould for sampling during the melting process to control the steel quality.—P. K.

Investigation of Contamination in Castings with the Aid of Radioactive Isotopes. B. B. Gulyaev, Yu. F. Borovskii, Z. V. Sigalova and E. S. Sokolova. (*Liteĭnoe Proizvodstvo*, 1956, (8), 25–27). [In Russian]. An account is given of an investigation in which radioactive W was used as a tracer to detect non-metallic inclusions due to the mould mixture in steel castings. The tracer in the form of an aqueous suspension was mixed in with the mixture. Most attention was given in the experiments to erosion of the gate in sand-clay moulds, an insert of tracer-containing mixture being placed in the horizontal channel. In further experiments some of the mixture was sprinkled on to the metal surface before pouring. The distribution of radioactivity in the castings under various pouring conditions is illustrated.—S. K.

Planning and Preparation of Production in Iron Foundries. S. Hargitay. (*Kohászati Lapok*, 1952, **7**, Nov., *Ontöde*, 251–259). The principles of the planning and preparation of production in grey iron foundries are comprehensively discussed.—P. K.

Automation and New Processes Offer New Opportunities for Cutting Foundry Costs. L. Wood. (*S.A.E.J.*, 1957, **65**, Aug., 57–59). A discussion of automation and of sand reclamation, shell moulding, CO_2 bonding and hot-blast cupolas is given.

HEAT-TREATMENT AND HEAT-TREATMENT FURNACES

Coding Heat Treating Data. (*Steel*, 1957, **141**, Aug. 26, 74). A simple coding system for specifying heat treatments, suitable for use on blue prints, is explained. Letters, numbers and symbols represent the heating medium and temperature, quench and tempering conditions.—D. L. C. P.

Furnace Atmosphere Analyzers. W. L. Besselman. (*Steel Proc.*, 1957, **43**, Sept., 517–523, 525). Dew point, infra-red, hot wire, combustible and other systems and automatic control methods and sampling are reviewed.

The Application of the Endothermic Atmosphere Generator and Automatic Atmosphere-Control Instruments to Australian Fuels. N. K. Koebel. (*J. Austral. I. M.*, 1957, **2**, Aug., 27–45). The endothermic generator is described and its applications to neutral hardening, carburizing, carbonitriding and vertical radiant tube heating discussed. The design and use of control instruments is then reviewed with conclusions on the properties of Australian town's gas and its metallurgical uses.

The Demag Electric Furnace in the Ferrous and Non-Ferrous Processing Industries. Hassler. (*Demag News*, 1956, (144), 1–4). Installations are illustrated with descriptive captions.

Surface Hardening by Oxyacetylene Torch. M. Vilez. (*Rev. Soudure*, 1957, **13**, (2), 67–77). [In French]. The author discusses the advantages to be obtained from local hardening of steels and how this can be done economically and simply by means of the oxy-acetylene burner. Practical techniques and the types of steel which can best be surface hardened are described.—M. D. J. B.

Flame Hardening Equipment Controls Complex Heat Pattern. (*Indust. Heating*, 1957, **24**, May, 924–926). The equipment for selective hardening of a hyperbolic shaped roller is described.—A. D. H.

Mechanized Selective Hardening of Yoke-Type Axle Shafts. K. M. Yeager. (*Indust. Heating*, 1957, **24**, July, 1324, 1326,

1328). A lead pot with a rotary conveyor mechanism is described.

Heating and Flattening of Steel Sheet Accomplished Simultaneously in New Furnace. (*Indust. Heating*, 1957, **24**, May, 983–984). A Waltz gas-fired air recirculating furnace fitted with an hydraulic unit for flattening aircraft wing skins during tempering or precipitation hardening is described.

Sulphurizing Surface Hardness of Steel. Morphology and Characteristics of Layers. N. Collari and P. Virdis. (*Met. Ital.*, 1957, **49**, March, 159–169). [In Italian]. The layers obtained on steel by a "sulphurizing" hardening treatment to give wear resisting and antifriction properties are examined chemically and metallographically. The authors show that the treatment, which is carried out at a temperature lower than the critical range in a bath containing a sulphur and a cyanide compound, causes a marked enrichment of C, and to a lesser degree of S and N, limited to a thickness of 1/10 mm. Hardening is by two layers morphologically different corresponding to solid or pseudo-solid solutions which in turn harbour secondary reactions. A brief review is given of the chemical and physical properties of these layers which have good antifriction properties. (28 references).—M. D. J. B.

Gas Carburizing Ring Gears and Pinions in a Continuous Unit Featuring Versatile Quench Facilities. (*Indust. Heating*, 1957, **24**, May, 928–930, 942). Ring gears and pinions are carburized to a depth of 0·050–0·060 in. at 1700° F quenched at 1400° F, followed by tempering in an automatic furnace. Quenching can also be performed manually.—A. D. H.

Automatic Batch Furnace Improves Quality and Increases Production. M. Kober. (*Indust. Heating*, 1957, **24**, May 1061–1068). A furnace used for bright hardening, carbonitriding and carbon restoration is described. It is heated by radiant tubes and a vestibule enables a new charge to be loaded while the previous batch is being quenched in a tank situated partially below the furnace.—A. D. H.

Surface Hardening of Steels. O. Dorigo. (*Ing. Mecc.*, 1957, **6**, June, 45–53). [In Italian]. After a brief review of the theoretical principles of case-hardening by carburizing, nitriding and carbonitriding, the author describes the practical processes to be employed, with particular reference to modern case-hardening techniques employing gas. The economics of the process are discussed showing how it can influence production costs.—M. D. J. B.

Metallurgical Aspects of Induction Heating. H. B. Osborn jun. (*Indust. Heating*, 1957, **24**, June, 1102–1105, 1111, 1112, 1114, 1116, 1254; July, 1350–1352, 1354, 1356, 1358, 1360, 1362. The expression for depth of penetration is given and the relation of diameter to rapidity of quenching is shown for surface hardening. The effects on various steels in terms of structure and carbide solution rates and diameter-time-frequency data are shown, with the effects of initial structure. Depth of hardness, power density and bar diameter are related to speed of travel and surface hardening and other treatments and the physical properties resulting are reviewed.

Nitriding Process. R. W. Allott. (*Metal Treatment Drop Forging*, 1957, **24**, Aug., 335–338). A review of the process, its use for various types of steel and various improvements suggested from time to time is given.

The Role of Degree of Dissociation of Ammonia Gas in Nitriding Processes. T. Tomöry. (*Kohászati Lapok*, 1956, **11**, May, 199–206). A minimum content of 3–4% NH_3 is necessary in atmospheres for efficient nitriding. The N_2 in the nitriding mixture furthers the diffusion of the nitrogen, arising from the dissociation of iron nitride in the surface layer, into the nitride case. A thick nitride case can be obtained by using a nitriding mixture with 80–90% N_2. Since N_2 is one quarter the price of NH_3 and considering the shorter time necessary to obtain the same case thickness, the use of a nitriding mixture with high N_2 content is suggested.

Continuous Normalizing and Heat Treating Equipment for Steel Plate. H. Drever and N. K. Willis. (*Iron Steel Eng.*, 1957, **34**, June, 125–130). This article describes a large fully automatic continuous high output plate heat treating line designed primarily for armour and commercial heat-treated plate. Details are given of the transfer car arrangements, hardening furnace, pressure quench, tempering furnace, layout and cutting tables.—M. D. J. B.

100-Ton Gas-Fired Car-Bottom Furnace in Operation at General Electric. (*Indust. Heating*, 1957, **24**, July, 1344, 1346). The furnace is used for stress relieving, operating at 750° C.

Cascade System Gives Precise Temperature Control on Continuous Strip Annealing Lime. (*Iron Steel Eng.*, 1957, **34**, June, 168–170). The paper describes an interlocked instrument which provides temperature control. It uses a radiation pyrometer rapidly to detect the effects of load changes thereby permitting temperature control within narrow tolerances on a completely automatic basis.—M. D. J. B.

Cascade Control for Strip Annealing. (*Steel*, 1957, **140**, June 10, 150–156). The automatic temperature control on a continuous strip annealing furnace is described. Pyrometers in the heating and cooling zones control electrical input and cooling air flow respectively so that variations in strip dimensions and speed are allowed for.—D. L. C. F.

Difficulties in Controlling Annealing Furnaces for Malleable Cast Iron. (*Fonderie*, 1957, May, 229). The problems in operating annealing furnaces for malleable iron are briefly discussed with particular reference to the construction of the furnace, the type of burners used, and the positioning of thermocouples.—B. C. W.

New Boxes Give Annealing Gains. (*Metalworking Prod.*, 1956, **100**, July 13, 1069). A new type of annealing box for small steel pressings is described. It was designed for fabrication as a three-piece unit in light-weight wrought Inconel. The alloy has a high strength/weight ratio at high temperatures, resistance to corrosion and repeated heating and cooling.—M. A. K.

Effect of Prior Anneal Temperatures on 18-8 Wires. S. Storchheim. (*Wire Wire Products*, 1957, **32**, June, 641–643, 710–711). Non-magnetic austenitic wire is converted to ferromagnetic martensite on deformation and other ranges in mechanical and electrical properties also occur, this is reversed by annealing. Nb, Si, Mo and Cr aid and C, Ni and Mn retard conversion. Measurements of magnetic parameters are given with regard to prior anneal and degree of reduction.

New Ideas on the Structure of Carbonitrided Layers. B. Přenosil. (*Hutnické Listy*, 1957, **12**, (7), 597–604). It was observed that layers containing more than ~ 0·5% N show coherent microporous bands on some of the austenite grain boundaries. From their appearance and the conditions for their formation it is concluded that the separation of molecular N_2 incapable of diffusion from atomic N in solid solution is the cause where the local activity of the N is also a function of C activity. The pores occur on boundaries of differently orientated grains and nuclei form in disturbed regions between grain lattices. This appears to confirm Mott's theory of the so-called insular model of grain boundaries.

On the Texture in Iron Scale. VII. The Nature of the Texture at Intermediate Temperatures. V. I. Arkharov and Z. P. Kichigina. (*Fizika Metallov i Metallovedenie*, 1956, **3**, (2), 269–277). [In Russian]. It is confirmed that the intermediate stage of oxidation of iron is characterized by the presence of a rhombohedral crystal lattice, which gradually changes to cubic as the oxidation proceeds to a finish. The parameter of the crystal shows a corresponding decrease. The lifetime of this intermediate phase depends upon the temperature. Whilst at 600° it cannot be followed to the end, at 900° or above the transformation to the cubic lattice is sudden. Explanations are offered for all these phenomena; for the mechanism of oxidation; for the transition from the intermediate to the following stage and for the predominant role played by the dispersion of oxygen atoms.—L. H.

On the Texture of Iron Scale. VIII. Investigation of the "Intermediate" Stage of the Oxydation of Iron Alloy. V. I. Arkharov and Z. P. Kichigina. (*Fizika Metallov i Metallovedenie*, 1956, **3**, (3), 468–470). In this section the investigations extended over alloy iron in contrast with those on pure iron which were previously published. They covered binary alloys of iron with Cr, Ni, Mn, W, C and Si in various concentrations.—L. H.

On the Texture of Iron Scale. X. The Texture in Wüstite Scale. V. I. Arkharov and M. I. Simonova. (*Fizika Metallov i Metallovedenie*, 1957, **4**, (2), 278–290). [In Russian]. The texture appears in the scale when the oxide at the surface consists of the single phase, wüstite, and under conditions which exclude the formation of higher iron oxides. The crystallographic forms depend on the conditions of the oxidation centres and on the temperature. The types are: (100), (410), (210), (430) and (110). The relation between

the texture and the external conditions of oxidation conform to the mode of adsorption of the oxygen.—L. H.

On the Structure of Haematite in the Outside Layer of Iron Scale. V. I. Arkharov and B. S. Borisov. (*Fizika Metallov i Metallovedenie*, 1956, **3**, (3), 460–467). In the first stages of oxidation, the haematite lattice contains in the surface zone a surplus of atoms, but the concentration of a surplus of oxygen is very small and the parameter of the lattice is practically the same as for stoichiometric haematite. In the succeeding stages of oxidation the growth of surplus oxygen atoms destroys the solidity of the lattice and causes its reconstruction. The appearance of vacant spaces in this surface layer favours the diffusion of the iron from the interior to the damaged layers due to which the oxidation is speeded up. In the final stages this oxidation at low temperatures is very prolonged, but a rise in temperature shortens it greatly. Below 700° it is difficult to observe the second stage, whilst above 800° the first stage is not noticeable.—L. H.

On the Decarburization of Steels. M. Someno. (*Tetsu to Hagane*, 1957, **43**, Mar., 301–303). [In Japanese]. Data are given for the effect of water vapour on the decarburization of 1% Cr steel. The reaction velocity is plotted against pressure of water vapour for non-chromium and 1% Cr steel. The effects of Al, Ni, Si and Cr in amounts up to 2% are shown for decarburization at 820° C.—K. E. J.

Stress Relief of Cast Iron Cylinders for Rolls by Induction Currents. S. Stefanescu, D. Cadariu and S. Manoliu. (*Met. Constr. Masini*, 1957, **9**, (6), 33–35). [In Rumanian]. A full description is given of a heater using induction currents capable of taking cylinders of 650 mm diameter by 1300 mm and providing the best conditions for stress relief, which have been found to be a temperature between 500 and 550° at a rate varying as required between 20 and 160° per h.

Formability of Flat Spring Material. J. B. Beckwith. (*Product Eng.*, 1957, **28**, Sept. 16, 125, 127). Annealed and pre-tempered materials are shown graphically.

Continuous Strip Annealing Line has Precise Temperature Control. Steel Co. of Canada. (*Blast Furn. Steel Plant*, 1957, **45**, Sept., 1024–1025). The cascade control system is described, using radiation pyrometers.

The Relation between Annealing and the Ferrite Grain-Size of Electric Resistance Welded Pipes. Y. Shimokawa. (*Tetsu to Hagane*, 1957, **43**, Mar., 278–280). [In Japanese].

Study on High Speed Tools. XVIII. Water and Air Annealing of High Speed Steels (SKH3 and SKH6). H. Hotta. (*Tetsu to Hagane*, 1957, **43**, Mar., 298–299). [In Japanese].

Studies on Acid-Resisting High-silicon Iron. IV. Effects of Cooling Rate and Annealing on Mechanical Properties and Corrosion Resistance. K. Akamatsu. (*Tetsu to Hagane*, 1957, **43**, Mar., 203–205). [In Japanese]. Results are given for irons containing approx. 15% Si, showing improvements in transverse strength, hardness and bending properties as moulds were used in the order dry sand–green sand–shell–metal moulds. Loss in weight by corrosion in HCl and H_2SO_4 was little affected. Increase of annealing temp. between 400° and 800° C slightly increased both the transverse strength and the weight loss by corrosion.—K. E. J.

The Relation between the Cold Working, Annealing and Ferrite Grain-Size of Electric Resistance Welded Pipes. I. Killed Steel Pipes. T. Yamamoto. (*Tetsu to Hagane*, 1957, **43**, Mar., 280–281). [In Japanese]. Variations in ferritic grain size and width of grain growth are shown for annealing temperatures of 650°, 700° and 750° C and times from 30 sec to 20 h.—K. E. J.

Ageing and Oxygen in Technical-Grade Iron. E. Maurer. (*Abhandlungen der Deutschen Akademie der Wissenschaften zu Berlin*, 1956, 152–173). The author discussed the influence of Al, Si, O and N on the ageing of steel. The importance of efficient normalizing is stressed. Quenching in water from 950° C prevents ageing. Precipitations of carbides and nitrides cause ageing of steels. (48 references.)—R. P.

On the Deterioration of Quenching Oils. IV. The Variation of Cooling Ability with Oxidation and Polymerisation of Oil. I. Tamura. (*Tetsu to Hagane*), 1957, **43**, Mar., 228–230). [In Japanese]. Details are given, for rapeseed and turbine oils, of the variation of cooling properties, viscosity, sludge formed, acid and iodine values for blowing times with air up to 200 h.—K. E. J.

The Action of Various Quenching Media on the Development of the Structure of Forgings 200 mm in Diameter, Manufactured from Chrome–Molybdenum Steel. A. Sponheuer and H. J. Fischer. (*Techn. Mitt. Krupp*, 1957, **15**, Sept., 87–94). The quenching action of water, special oil and normal mineral oil was investigated on forgings of 200 mm diameter made from three different Cr–Mo steels. The special oil produced a depth of hardening intermediate between that formed by water and normal oil, but no improvement of the core structure was observed.—L. D. H.

The Present Position in the Use of Salt Baths for the Thermal Treatment of Steels. N. Piriu. (*Met. Constr. Masini*, 1956, **8**, (9), 29–42). [In Rumanian]. The quenching baths are classified into four categories and the whole position is reviewed from the theoretical and practical viewpoint. Durferrit nomenclature is used and tables of indices and characteristics are supplied.—L. H.

Martensitic Steel Wire. S. Nishioka. (*Tetsu to Hagane*, 1957, **43**, Mar., 362–364). [In Japanese]. An apparatus for continuous quenching and tempering of mild steel wire is described. Mechanical properties are given for wires of 0·08, 0·14 and 0·22% C steels (0·10 passes in each case).

On the Heat-Treatment of Hot-working Tool Steel. E. Miyoshi. (*Tetsu to Hagane*, 1957, **43**, Mar., 233–235). [In Japanese]. For a steel containing 0·24% C, 6·01% W, 1·91% Cr, 0·46% V, equi-hardness curves are drawn showing the variations of quenched and tempered hardness with the distance from the quenched end of a Jominy test bar. For a steel containing 0·39% C, 1·06% Si, 0·51% Mn, 3·93% W, 1·04 Cr, 0·13% Mo, the effects of tempering temperature and of testing temperature on the Charpy impact value are shown for the water-quenched, air-cooled and slowly air-cooled conditions.—K. E. J.

Contribution to the Manufacture and Heat Treatment of Spring Strip for Clockwork and Similar Mechanisms. M. Marinescu-Firica and K. Horst. (*Met. Constr. Masini*, 1956, **8**, (3), 24–36). A full and detailed process is outlined for the manufacture and the heat treatment of these springs, and an investigation of the current production methods reveals various details which are still capable of improvement.—L. H.

Investigation of Tempering Conditions for Grey-Iron Castings. M. M. Kantor, E. V. Biryukova and A. P. Kulikov. (*Liteinoe Proizvodstvo*, 1957, (2), 17–18). [In Russian]. The investigation described aimed at finding the optimal values for grey iron castings of heating temperature, soaking time and cooling rate to secure in the shortest time maximal removal of stress while preserving sufficient pearlite. Four irons were used, covering the composition range: 3·09–3·44% C, 1·69–2·54% Si, 0·63–0·91% Mn, 0·074–0·161% P, 0·102–0·110% S, 0–0·19% Cr. Test pieces of different shapes were used to determine residual stresses and tendency to graphitization, cooling rate being studied with ring specimens. Results showed that cooling rates normally used in foundries are unnecessarily low.—S. K.

The Effect of Tantalum and Niobium on the Tempering of Certain Vanadium and Molybdenum Steels. A. K. Seal and R. W. K. Honeycombe. (*J.I.S.I.*, 1958, Apr., **188**, 343–350). [This issue].

ROLLING-MILL PRACTICE

Casting of Rolls from Reverberatory Furnaces. A. Schleicher. (*Kohászati Lapok*, 1953, **8**, Feb., *Öntöde*, 45–48). The author discusses the advantages of casting of rolls from reverberatory furnaces over cupola furnaces.—P. K.

A Protective and Exhaust Equipment for the Manufacture of Big Nodular Iron Rolls. G. Bella. (*Kohászati Lapok*, 1955, **10**, March, 45–47). The author describes the construction and use of protective and exhaust equipment applied in a Hungarian foundry manufacturing big nodular iron rolls.—P. K.

Some Problems of Chilled Roll Production. L. Bánhegyi. (*Kohászati Lapok*, 1952, **7**, Sept., *Öntöde*, 193–197). The influence of the alloying elements (C, Si, Mn, P, S, Ni, Cr, Mo) and of the melting temperature on the quality of chilled rolls is discussed. The conditions for a high melting temperature in cupolas are specified and the most suitable moulding and casting techniques are described. Melting in reverberatory furnaces and modification with ferrosilicon are suggested.

Twin Casting of Rolling Mill Rolls. P. D. Mikhalev. (*Stal'*, 1957, (8), 758–759).

Sheet Mill Rolls Preheated by Gas before Assembly. L. I. Konstantinova, Ya. M. Lemlekh and L. A. Frenkel'. (*Stal'*, 1957, (8), 724–727). Gas heaters were more economical and gave more uniform heating than induction heaters.

The Design of Bearing Sealing Rings for Steel Mill Equipment. G. G. Davletbaev. (*Stal'*, 1957, (8), 760–762).

On the Gripping of the Metal by Blooming Mill Rolls. S.V. Makaev. (*Stal'*, 1956, (12), 1089–1094). [In Russian]. Rolling practice at various Soviet blooming mills is compared and experiments with increased reductions at Novo-Tagil' are described. These showed that the true reduction could be raised to 110–115 mm, enabling productivity to be increased by 20–25%.—S. K.

Reconstruction of Individual Units of Slabbing-Mill Equipment. B. M. Tsirlin. (*Stal'*, 1957, (3), 232–238). [In Russian]. Modifications made in the rollers and roller tables, equipment for removal of scale and scrap and the horizontal-roll bearings of the 1100-mm roll-diameter slabbing mill (the first Soviet built one) at the Zaporozhstal' works are described. They have given a 32% productivity increase.—S. K.

Copper Segregation on the Surface of Rolled Mild Steels. R. Hantos and F. Boda. (*Kohászati Lapok*, 1955, **10**, March, 123–124). The results of spectroscopic analysis of the surface layer of mild steel billets 3·35 in² show that the copper content on the surface is up to ten times higher than at depth of 0·2 in. or more.—P. K.

The Use of Cold-formed Special Profiles for Welded Standard Multi-Purpose Structural Components in Light Steel Structures. O. Jungbluth. (*Schweissen u. Schneiden*, 1957, **9**, June, 248–252). A description is given of a standardized design in the field of steel frame buildings. The main structure consists of a welded three-dimensional lattice girder made of cold-formed special sections. Cold working raised the yield stress to between 40 and 50 kg/mm² as compared with 24 to 27 kg/mm² of the original material (St 37).—U. E.

Experiment in the Rolling of Economic Sections. V. D. Smirnov, N. K. Ryabokon', S. V. Gubert, I. Ya. Vinokurov and G. D. Feigin. (*Stal'*, 1956, (12), 1086–1089). [In Russian]. Experiments have confirmed that lightened forms of girder can be rolled with ordinary rail-girder equipment at the expense of productivity and metal economy.—S. K.

The Economic Effectiveness of Producing Lightened Rolled Sections. L. L. Zusman. (*Stal'*, 1956, (12), 1099–1103). [In Russian]. The economics of producing the "economical" rolled sections as compared with previous practice are analysed. Losses of rolling-mill productivity, capital cost charges and reductions in metal requirements per foot run of section are among the factors considered.—S. K.

The Planning of Large Rolling-Mill Plants for Rod and Wire. H. P. Lemm. (*Berg- u. Hüttenmänn. Monatsh.*, 1957, **102**, 93–114). The author discusses the problems involved in the planning and design of large rolling mills. He quotes several examples of recently built rolling mills. The modern concept of reduction per pass and of the type of calibration are discussed. High rolling speeds are dominant in modern mills. Auxiliary plant and electric drives are also dealt with.—T. G.

Developments in Planning and Design of Bar, Rod and Wire Mills for High-quality Steel in Sweden. E. Norlindh. (*Berg- u. Hüttenmänn. Monatsh.*, 1957, **102**, April, 83–92). N. describes the extension of a rolling mill from five to seven stands. (The five-stand mill was described in *Stahl u. Eisen*, 1955, **75**, 700). He reports on experience obtained in the operation of the seven-stand mill.—T. G.

Modern Methods of Making Sheets. L. A. de Araujo. (*Bol. Assoc. Brasil Met.*, 1957, **13**, Jan., 51–62). [In Portuguese]. The author discusses, with illustrations, the various methods of sheet manufacture from manual operation to continuous mills, and gives a comparison of the products so produced, the space and capital cost requirements of such plant and the characteristics of the various products.—P. S.

Continuous Cold-Rolling of Steel Sheet. A. Doria Machado. (*Bol. Assoc. Brasil Met.*, 1957, **13**, Jan., 5–40). [In Portuguese]. In this review, the author briefly discusses rolling theory and practice, giving calculations of operational data for a 4-stand mill. Further calculated examples for power and tension requirements for temper rolling are given after a description of the importance of tension, lubrication, cooling, and finish rolling. In conclusion, the common hot and cold-rolling defects are briefly discussed.—P. S.

The Rolling Mill Plant of the Vereinigten Österreichischen Eisen- und Stahlwerke Linz a.d. Donau. A. Lovay. (*Berg- u. Hüttenmänn. Monatsh.*, 1957, **102**, April, 135–146). The author describes the rebuiding and extension of the works since 1945. Auxiliary plant and equipment are included in this description. The works produces plate, sheet, and wide strip.—T. G.

Investigation of the Gripping Power of Plate-Mill Rolls. M. M. Gorenshtein. (*Stal'*, 1957, (3), 239–242). [In Russian]. In this article results of a detailed investigation of deformation at the Il'ich works are used for the consideration of roll-gripping power of three three-high plate mills. It was found that the power was greatest when one steel and two cast iron rolls were used: this required subsequent rolling of the plate between iron rolls to improved surface quality. Optimal conditions for carbon steels and also for Ni-, Cr- and Cu-containing low-carbon steels are given.—S. K.

Rebuilding and Modernization of Rolling Mills of the Austrian Iron and Steel Industry since 1945. O. Kammerhofer. (*Berg- u. Hüttenmänn. Monatsh.*, 1957, **102**, April, 50–66). K. gives a detailed review of the rebuilding and modernization of every rolling mill in Austria since 1945, as these, after the war, were either dismantled or so out of date that in fact they all had to be rebuilt. The rolling mill output reached $1 \cdot 3 \times 10^6$ metric tons in 1955, i.e. 300% of the 1937 output. The extension programme is still progressing.—T. G.

The Determination of Spread in the Hot-Rolling of Steel. M. Wenzel. (*Neue Hütte*, 1957, **2**, Apr., 227–230). The impression derived for the determination of flattening during hot rolling agrees with that developed by B. P. Bachtinov and M. M. Tchernov which is characterized by convenience in use.—L. J. L.

Production and Quality of Rolled Steel for the Brazilian Automobile Industry. P. Silva. (*Eng. Min. e. Met.*, 1957, **25**, Jan., 9–18). [In Portuguese]. The author points out that about 250,000 t. of rolled steel will be required in 1960 in order to meet the requirement that, by then, 90% of vehicle parts should be of national manufacture instead of the present 50%. He then goes on to discuss in detail the problems of quality control of the manufacture of rolled products.—P. S.

The Foundation for and Protection Against Damages Due to Mining Operations of a Hot and Cold Strip Mill. A. Degen. (*Stahl u. Eisen*, 1957, **77**, July 25, 1018–1027). A detailed description of the work done for the foundation of a six-stand rolling mill and its adjustment in case of further settlement of the ground are given.—T. G.

Seamless Tube Giant Producing at Sault Ste. Marie. (*Canadian Metalworking*, 1957, **20**, July, 46, 48, 49). The new automatic mill of the Mannesman Tube Co. is described.

Rolling Mill Drives Employing Amplidyne Control and Rectifiers. H. Opitz. (*Berg- u. Hüttenmänn. Monatsh.*, 1957, **102**, April, 77–83). The advantages obtained by using Amplidyne drive and rectifiers for D.C. motors in rolling mills are discussed and compared.—T. G.

Converter Installations in Modern Rolling Mills. H.-J. Mau. (*Neue Hütte*, 1957, **2**, May, 299–307). A comparison is made between rotary transformer drives and rectifier drives which are increasingly coming into use in Germany. The various systems available are described. Rectifier-driven reversing mills, Leonard-transformers with rectifier-exciter circuits, rectifier-driven continuous mills, and winch operation with variable speed limitation are discussed.—L. J. L.

Descaling during Hot Rolling. G. Nyberg. (*Jernkontorets Ann.*, 1957, **141**, (1), 37–59). [In Swedish]. An investigation was made of the influence of nozzle design on descaling efficiency, various nozzles being tested at different pressures. Details are given of the method employed for measuring and calculating jet impact and distribution. A comparison was made between nozzles having circular jets and deflector plates and free-jet nozzles. Recommendations are made concerning nozzle design, spacing and water pressure.—G. G. K.

Electrical Equipment for a Cold Cut-Up Line. (*Metallurgia*, 1957, **56**, Aug., 57–60). An account of the Steel Co. of Wales installation.

MACHINERY FOR IRON AND STEEL PLANT

Structural Design of Steelworks Electric Overhead Travelling Cranes. D. Buchanan and R. G. Tyler. (*J.I.S.I.*, 1958, Apr., **188**, 371–388). [This issue].

WELDING AND FLAME CUTTING

Arc Welding. O. Eiro. (*Tek. Kemian Aikakauslehti*, 1957, **14**, June 29, 209, 211–212). Chemical reactions in the welding arc and the influence of the coating materials of

soldering electrodes are explained. The superiority of arc welding over rivetting and the various uses of welding techniques are described.

Flame-Hardening of Filler-Welds. V. Trunschitz, (*Schweisstechn.*, 1957, **11**, July, 80–84; Aug. 93–95). The theory of hardening is discussed with special reference to the fundamental principles of flame hardening. Formation of ferrite should be avoided. The properties of various gas mixtures are considered. Practical applications include flame hardening of wheels and similar round sections. Costs are reduced and the running life of wheels is prolonged. The flame-hardening machine is described.—R. P.

Welding and Related Procedures Encountered in a Modern Steel Foundry. S. W. Gearhart jun. (*Welding J.*, 1957, **36**, July, 693–702). An account is given of the interdependence of welding and foundry industries. Welding is used to improve casting quality, simplify design and to incorporate castings into welded structures. Many examples are illustrated.

The Possibilities of Welding in the Field of Highly Stressed Parts. A. Maier. (*Rev. Soudure*, 1957, **13**, (2), 78–92). [In French]. The author describes the vast possibilities which await welding in the field of pressure vessels and in all highly stressed structural parts. Examples of whole weldments are given together with technical data and illustrations.

Experiences with Austenitic Heat-Resistant Welds. W. Ruttmann, K. Baumann and M. Möhling. (*Schweisstechn*, 1957, **11**, Jan., 6–10, Feb., 19–22). The welding of corrosion- and heat-resistant austenitic pressure vessel steels is investigated and test results are presented in graphical form. It was found that stabilized steel behaves more favourably. As there exists the danger of stress corrosion, a stress relief treatment is recommended.—U. E.

Considerations on the Welding of Carbon and Low Alloy Steels of Various Grades used in the Construction of Oil Plants. H. Gerbeaux and H. Granjon. (*Soudage Techn. Connexes*, 1956, **10**, July-Aug., 175–183). Statistics of steel production and demand foreshadow a risk of scarcity in constructional welding steels used in the oil industry and the danger of having to use steel of inferior quality. The revision of specifications by dispensing with some useless clauses and filling in of gaps is advised. It is little use specifying the method of manufacture, e.g. whether O.H. or basic Bessemer steel, or insisting on a particular composition. After discussing the behaviour of steels in welded constructions in relation to composition, mechanical properties and the effects of ageing and quenching, it is concluded that the most important properties are elasticity, elongation, transition temperature of notch bar impact value, and effect of ageing and quenching. It is also desirable to limit the diversity of qualities of steels demanded or proposed.

Building-up, Cladding and Plating Assemblies by Welding. H. Gerbeaux. (*Soudage Techn. Connexes*, 1956, **10**, May-June, 148–153). The various arrangements and operating principles of welding techniques for conditioning surfaces to resist corrosion, friction, abrasion and pitting are described. Details of building-up techniques for various alloys are given.

Some Considerations on the Welding of Alloy Steels Used in the Construction of Modern Heat Engines. A. Lüthy. (*Soudage Techn. Connexes*, 1956, **10**, May-June, 117–131). After considering the welding problems that arise in the construction of heat engines the welding techniques for many types of heat-resisting alloy steels used in steam and gas turbines are reviewed. Various types of weld fillets are discussed and their microscopical structure described and illustrated. Discussion is reported.

Welding Thick Plate for Nuclear Power Plant. (*Welding Metal Fab.*, 1957, **25**, Aug., 298). A special electrode, Fortrex 35A, is described.

How To Make 17-7 PH Honeycomb Panels. P. M. Allen. (*Iron Age*, 1957, **180**, July 11, 99–101). The method of making lightweight, high strength all-steel honeycomb panels for aircraft is described. Metal for both core and skin is Armco 17-7 PH, a precipitation hardening stainless steel with 0·07% C; 17% Cr; 7% Ni. The special processes for surface cleaning and brazing are explained.—D. L. C. P.

"Konstruicten in Stahlblech." E. H. Lloyd. (*Sheet Metal Ind.*, 1957, **34**, June, 435–448, 460). A detailed and illustrated report on the recent exhibition on the design and application of structures in sheet steel, held at the Technische Hochschule, Hannover, Germany.—A. H. M.

Problems Associated with the Welding of T-1 Material. P. C. Arnold. (*Welding J.*, 1957, **36**, Aug., 373s–381s). Field welding of pressure vessels is considered in which transverse cracking of weld metal tended to occur. A laboratory test programme was carried through and the restraints necessary to produce cracking were determined. Rebaking of the electrodes prevented cracking. Explosion bulge tests at 30°, 0° and −50° F were carried out. Moisture contents of 0·2% are too high and 24hr. at 500° or 1 hr. at 800° F is needed to bring it down to 0·1%. Improvement of electrodes is urged.

Metallurgy of the Welding of Certain Austenitic Heat and Corrosion Resistant Alloys. A. H. Waterfield and R.-P. Culbertson. (*Welding J.*, 1957, **36**, Aug., 360s–365s). Corrosion-resisting and heat-resisting alloys, Ni-Mo-Fe, Ni-Mo-Cr-Fe, Fe-Cr-Ni-Co and Ni-Cr-Mo-Fe and other compositions are discussed. Preparations, properties, structures and effects of oxidation are reviewed.

Contribution to the Study of Backing Electric Arc Welds. J. Daivier. (*Rev. Soudure*, 1957, **13**, (2), 102–111). [In French]. The importance of finishing off the underside of welds is stressed. Practices demanded by different specifications are reviewed and the results obtained by different methods and the uses of a variety of electrodes are described. Tables of statistical data and illustrations showing the results obtained are given.—M. D. J. B.

Fabrications in Stainless Steel and Titanium. (*Welding Metal Fab.*, 1957, **25**, July, 234–238; Aug., 299–303). Methods of pressing and welding by J. R. Bramah & Co. Sheffield are described.

Is Welding Ready for High Alloys? H. J. Nichols. (*Canad. Metals*, 1957, **20**, Apr., 36, 38). Factors introduced by the use of high-strength steels are discussed.

Repairing Machine Tool Castings by Welding and Heat Treatment. N. Cseh. (*Kohászati Lapok*, 1956, **11**, (9), 197–200). Areas of bearing surfaces repaired by welding using grey cast iron welding rods must be of the same hardness as the remainder of the surface. The structure and composition of the rod and the weld are given. The author gives details of normalizing and stress relieving processes for eliminating the undesirable hardness difference.—P. E.

Temperature Distribution and Power Consumption in Inductive Heat Treatment of Circumferential Weld Seams of Steel Tubes. H. Geisel. (*Schweissen u. Schneiden*, 1957, **9**, April, 156–161). The heat conductivity and power requirements are calculated and the critical results are plotted in graphs.—U. E.

Experiences with the New Method of Friction Welding. B. Vrána. (*Zváranie*, 1957, **6**, (4), 105–109). [In Czech]. The principles and applications of the method are surveyed. It is shown that the conical seatings of twist drills may be attached to the drills proper by friction welding. The heat is obtained as the result of the friction between the flat surfaces of the drill and the seating, one of which is stationary, the other rotating in the jaws of a drilling machine. The scope and limitations of the method are discussed.—P. F.

Consideration of Metallurgical Problems in Connection with the Development of New Welding Electrodes. Examples of Successful Applications of these Electrodes. Future Trends. K. L. Zeyen. (*Schweissen u. Schneiden*, 1957, **9**, May, 186–193). The physical properties of arc weld deposits obtained with coated electrodes are discussed. It is shown that TiO_2-coated electrodes gave good quality welds, and deep penetration electrodes are considered to be very economical and especially suitable for welding double fillet joints.—U. E.

Evolution of High-Tensile Weld Metal with Low-Hydrogen Electrodes. D. C. Smith. (*Welding J.*, 1957, **36**, July, 677–692). The 1957 Adams Lecture. Defects of electrodes containing cellulosic or H_2-bearing mineral type coatings are noted and the effects of variable moisture contents. The production of a weld metal of 110,000 psi minimum yield and 20% elongation is described and the establishment of max. moisture limits. Studies on coatings of MIL-G-986 B, MIL-230-16 and MIL-260-15 electrodes and moisture absorption and removal are reported, and alloys developed to overcome the temper-brittleness of Ni-Mo-V weld metal are reported and alloys for aircraft use with 125,000–210,000 psi which are heat-treatable are mentioned. Ultra-strength materials of 220,000–300,000 psi are reviewed and mechanical properties given.

New Fluxes Simplify Welding. (*Steel*, 1957, **140,** June 17, 110). Applications of a new type of bonded flux called "Arcosite" are described. Flux composition can be adjusted to help weld properties, and alloy additives do not oxidize as maturing temperatures are low. It is valuable for automatic submerged arc welding of stainless steel, and overlay welding.—D. L. C. P.

PROTECTIVE COATINGS

Selective Plating: A "Putting-On" Tool. C. A. Kuster and H. R. Taylor. (*Metalw. Prod.*, 1957, **101,** Nov. 15, 2048–2049). The Dalic process is outlined where Cu or Cd can be applied locally, also Cr or Ni. Uses are briefly discussed.

A Study of Concentration Polarization at Working Electrodes. R. N. O'Brien and H. J. Axon. (*Trans. Inst. Met. Fin.*, 1957, **34,** Winter, 41–52). An optical study by an interference system was used and three components were identified, two of which vanish when the current is stopped while the third fades more slowly and may be identified with the concentration polarization layer already studied.

Cyclic Electrolysis. A. Hickling and H. P. Rothbaum. (*Trans. Inst. Met. Fin.*, 1957, **34,** Winter, 53–66). The effect of periodic reversal of the current on concentration overpotential and current efficiency was investigated.

PROPERTIES AND TESTS

Materials Selector. (*Mat. Des. Eng.*, 1957–58, Reference Issue, **46,** mid-Sept., pp. 420). Properties of ferrous, non-ferrous and non-metallic materials are tabulated including tensile and creep strengths, hardnesses, elasticity, resistivity, m.p. and thermal expansions, corrosion resistances and effects of irradiation. Properties and uses of irons and all classes of steels are then given, followed by similar tables of other materials including clad and precoated metals and electroplates. Various parts, forged, welded, screws and tubing are then recorded and, finally, a list of suppliers is added.

Lattice Defects and Strain-Gauge Factors. E. W. Kammer and I. Vigness. (*Proc. Soc. Exper. Stress Anal.*, 1957, **15,** (1), 179–184). Resistivity changes in wires are due to several factors having different resistance-strain coefficients, all independent of temperature. High-resistivity wires are nearly independent of cold-work also as their resistivities depend mainly on a single factor.

On the Preparation of Iron Single Crystals of High Purity and Certain Properties of the Metal. J. Talbot. (*Thèses Fac. Sci. Paris*, 1956, pp. 50). A method of electrolytic preparation with annealing in H_2, analysis by neutron activation, microanalysis for O, C, S, and N, is described. A method of growing crystals is described with an account of polygonization phenomena and a study of its occurrence and the effect of impurities. Properties studied include hydrogen saturation and mechanical properties using Armco, pure and pure polygonized irons.

High-Temperature Furnaces. (*Wire*, 1957, Aug., 30–31). A furnace working in the range 1850–1950° C with a tube 3·93 in. diameter × 36 in. long is described, details of temperature distribution and particulars of design being quoted.—J. G. W.

Plastic Deformation and the Atomic Lattice. J. Orland. (*Met. Elect.*, 1956, **20,** Aug., 45–56). An account of X-ray studies of normal and deformed crystal lattices.

The Use of Paraffin Wax as a Model Material to Simulate the Plastic Deformation of Metals. Part II—Practical Applications of this Technique. J. W. Barton, C. Bodsworth, and J. Halling. (*J.I.S.I.*, 1958, Apr., **188,** 321–331). [This issue].

Dynamic Tensile Tests on Steel. R. M. O. Weinbaum. (*Bol. Assoc. Brasil Met.*, 1957, **13,** Jan., 41–49). [In Portuguese]. These tests were made by mounting specimens of mild steel in the reversed hammer of an Amsler impact testing machine so that the test piece was shock-loaded in tension on release of the hammer. In all, five varieties of specimen shape were used to show that, (i) there is a straight line relationship between specimen volume and absorbed energy, (ii) the specific energy absorbed per unit volume (averaging about 1550 kg cm/cm^3) is independent of the volume of the test piece, (iii) there is close agreement between experimental and calculated results.—P. S.

Properties Revealed by Tensile Tests on Pearlitic Nodular Irons. G. N. J. Gilbert and K. B. Palmer. (*Inst. Brit. Found. J.*, 1957, **50,** Sept., 441–457). At room temperature strength depends upon the ductile-to-brittle transition temperature. Materials where this is high have low tensile strength. Normalizing decreases the transition temperature and improves tensile properties, Si and P raise and Sn and As decrease it. Some irons may be brittle in the range 300–600°, all decrease in strength above ~ 300° C and some do not increase in elongation, the latter are said to exhibit brittleness at high temperature. Traces of As or P produce superior high-temperature properties. Tensile strength decreases in water or mercury, generally more in normalized than in as-cast irons. Organic solvents have no effect.

Cast Steel Wheel Tested to Destruction. (*Commonwealth Eng.*, 1957, **44,** July 1, 80–81). Tensile and bend tests were also carried out.

Reasons for Variations in the Ductility of Steel at High Temperatures. M. I. Vinograd. (*Stal'*, 1957, (3) 254–260). [In Russian]. In the investigation described the influence of different factors on the high-temperature ductility of an alloy not possessing a two-phase structure was studied. The alloy (20% Ni, 80% Cr approx) was melted in crucibles with basic or acid lining, heating temperatures and deoxidizing conditions being varied. The results showed that one of the main reasons for the low ductility of certain heats was the presence of O_2 in the form of vitreous phases or other low-melting oxides, silica formed during melting tending to produce these substances in highly dispersed states. Ways in which liquid metal can become saturated with silica are discussed. The conclusions are considered to apply to other alloys, including steels.—S. K.

The Design and Evaluation of High-Strength Bolted Steel Joints. B. Hamm and O. Kehrmann. (*I.S.I. Co-op. Trans. Service No.* 592: from, *Industrie-Anzeiger*, 1957, Jan. 15, pp. 10). The design and properties of the HV joint are reported. It is used for the erection of steelwork by unskilled labour.

High Strength Bolts in Steel Construction. B. Hamm and O. Kehrmann. (*I.S.I. Co-op. Trans. Service No.* 591: from *Industrie-Anzeiger*, 1956, Dec. 18, pp.14). The limits of force-bearing for rivets and screws are obtained and the advantages of high strength bolted joints are pointed out.

Fractographic Method for Controlling the Quality of Heat Treatment. Z. N. Krasil'shchikov and E. N. Shvach. (*Zavodskaya Laboratoriya*, 1956, **22,** (9), 1056–1061). [In Russian]. The continuation of previous work on the detection of faulty heat treatment of steels by the inspection of fractures at magnifications sufficient to show the structure of the brittle regions (fractography) is described. Photomicrographs of effects obtained with various types of structure are shown and their interpretation discussed. Explanations of the development of brittle fractures can be arrived at rapidly by this procedure: pearlitic and bainitic brittleness result in the fracture passing through the grain, while with temper brittleness and overheating the fracture follows grain boundaries.—S. K.

Influence of Power Cutting on the Endurance of Steels. G. B. Karpenko and A. I. Yatsyuk. (*Vestnik Mashinostroeniya*, 1956, **36,** (10), 32–34). [In Russian]. By power cutting the author understands the cutting of metals with maximum force with the help of special machinery so as to insure the highest productivity of labour at the given speed of work. Great interest resides in the elucidation under such conditions and of the characteristics of the steels. Experiments have been conducted in air and in water with suitable machines and the specimens subjected to loads of 5×10^6 in air and 20×10^6 in water. Results are tabulated.—L. H.

Test Pieces for Cold Bending Tests. B. A. Semin. (*Zavodskaya Laboratoriya*, 1956, **22,** (9), 1098–1099). [In Russian]. A brief account is given of an investigation into the causes of cracks on the compression side of bend test pieces bent to complete closure. It is provisionally suggested that such cracks are caused by the development of local secondary tensile stresses leading to embrittlement.—S. K.

Bend Testing Test Pieces with Stress Concentrators. E. S. Volokhvyanskaya. (*Zavodskaya Laboratoriya*, 1956, **22,** (9), 1095–1098). [In Russian]. Comparative testing of several structural steels for bending using test pieces with different types of stress concentrating irregularities in the tensile zone of the deformed metal is described. The main

indications obtained are: this type of bend test gives an independent and additional service characteristic of a steel (e.g. two steels which behaved similarly in tensile and impact tests were sharply differentiated); differences appear not only in the value of the bending angle corresponding to crack appearance, but also in how the crack develops; the method is especially suitable for detailed tests on new types of low-alloy structural steels.—S. K.

On Breakdown and Macro-fissure Marks Appearing in Parts of [Bending Test Specimens]. I. On Macro-fissure Marks. II. Relation between Results of Bending Test and Mechanical Properties. H. Ishizuka. (*Tetsu to Hagane*, 1957, **43**, Mar., 345–347; 347–348). [In Japanese]. I. Macro-fissure marks after bending of steel specimens are shown to have originated in inclusions. II. Results of the bending test are shown to be correlated with values of elongation and reduction in area, but not with other mechanical properties.—K. E. J.

Cold Bending of Steel Tube. I. Stress and Strain by Bending, and Limit of Bending. K. Takase. (*Tetsu to Hagane*, 1957, **43**, Mar., 236–238). [In Japanese]. Normal and shear stresses acting on the longitudinal section of a tube are determined for different angular positions between the inside and outside of the bend, for the cases of bends of 1·5, 2·0 and 3·0 × tube dia.—K. E. J.

Note on the Concentration of Stresses in Elliptical Fillets. A. Erra. (*Met. Ital.*, 1957, **49**, 590–517). [In Italian]. The author investigates the behaviour of elliptical fillets under bending and tensile stresses by means of photoelastic experiments. Stress concentration factors have been determined by fatigue tests carried out on specimens of two different steels. Experimental results show elliptical fillets to be effective in reducing stress concentration in bending stresses, but not in tensile stresses.—M. D. J. B.

Method of Testing Metal Specimens with Different Stress Concentrators in Static and Impact Twisting. I. G. Mikhailichenko. (*Zavodskaya Laboratoriya*, 1956, **22**, (9), 1081–1086). [In Russian]. A new machine for torsion testing with low and high rates of deformation is described and results obtained with ten forms of test pieces of an axle steel (0·35% C; 0·78% Mn; 0·28% Si; 0·034% P; 0·034% S) are presented and discussed. The rod test-piece forms differed in the nature of stress-concentration obtained (various types of notch, keyways, projections, etc.). Analysis of results showed that angle of twist is a sensitive criterion for the form of test piece and established the efficacy of the various stress-concentrating irregularities.—S. K.

Ordinary Machines for Twisting Barbed Wire Used for Rapid Torsion Tests with Hot Steel Specimens. V. A. Kubasov and Yu. I. Popov. (*Zavodskaya Laboratorya*, 1956, **22**, (11), 1366–1367). [In Russian]. A description is given of a machine type 2 used in barbed wire tests, and the manner in which it can be utilized for torsion tests on hot steel specimens at elevated temperatures. Results of actual tests are given and tabulated on steel Ct 3 at temperatures of 20, 100, 200, 300, 400 and 500° C.—L. H.

Method for Measuring Loads and Small Deformations in Impact Tension. Yu. Ya. Voloshenk-Klimovitskii. (*Zavodskaya Laboratoriya*, 1956, **22**, (9), 1090–1095). [In Russian]. Apparatus and a new method for tensile impact testing of metals have been developed. Conditions for obtaining reproducible results have been elucidated and the possibility of avoiding fluctuations on the load oscillograms established. Methods for investigating small plastic deformations during impact are proposed.—S. K.

Determination of the Limited Endurance of Steels Under Repeated Tensile Impacts. L. T. Timoshuk. (*Zavodskaya Laboratoriya*, 1956, **22**, (12), 1487–1489). [In Russian]. Experiments are described in which two steels were subjected to a very limited number of cycles of tensile impacts. Results showed that the initial stresses recorded higher effects than the subsequent ones and that the specimens under test tend towards a certain stable condition prior to rupture. By imparting alternating stresses of great and small loads the strength of steels is greatly increased.—L. H.

The Temperature Mosaic and Instantaneous Stresses of the 2nd Kind During Impact Deformation of Two-Phase Metals. G. P. Zaitsev and Yu. E. Bondarev. (*Fizika Metallov i Metallovedenie*, **3**, (1), 139–145). [In Russian]. When a metal contains constituents which have appreciably different resistances to plastic deformation, impact loading results in the instantaneous appearance of a temperature mosaic and of 2nd order stresses. The latter grow with the increase in plastic deformation. Despite their short duration, these stresses are superimposed on the stresses balancing the external load, thus increasing the susceptibility of the metal to brittle fracture.—L. H.

Low Temperature Properties of Steel Castings. British Steel Castings Association. (*Castings*, 1957, **3**, June, 22–23) Charpy V-notch test values are given.

Method of Determining the Relation between the Speed of Propagation of Plastic Deformation. D. A. Kal'ner. (*Zavodskaya Laboratoriya*, 1956, **22**, (9), 1086–1089). [In Russian]. The direct determination of the relation between the speeds of elastic and plastic deformations is described. Rakhmatulin's method (in which a flexible thread is broken by a transverse blow) was used, the thread here being a 1·23-mm diameter wire of type 18–8 steel with 0·20% C, hardened from 1100° C. In the tests the wire was attached to supports through fibre threads. Depending on the speed of the blow (250–300 m/sec) either the wire or the fibres broke and from this effect and measurements of deformation at different points of the wire the speed of plastic deformation was found.

Measurement of Static Deformations with Tensometers in a Variable Temperature Field. K. V. Semenov. (*Zavodskaya Laboratoriya*, 1956, **22**, (5), 573–579). [In Russian]. The special problems arising in the tensometric measurement of static deformations when temperature differences occur are discussed, with special reference to wire resistance strain gauges and Hugenberg-type mechanical tensometers in the range 0–200° C. The material presented includes data on the properties of Constantan wire in connection with temperature compensation, the preparation and fixing of the gauges, the fixing of compensating gauges and allowing for temperature differences between them and the working gauges, and the effects of temperature on mechanical tensometer results in two methods of use.—S. K.

On the Initial Stage of Plastic Deformation in Polycrystalline Metals and the Influence of the Size of the Grains. II. Iron. Ya. R. Rauzin and A. R. Zheleznyakova. (*Fizika Metallov i Metallovedenie*, 1956, **3**, (1), 154–161). [In Russian]. This study was made on pure iron with grain sizes from 0·06 to 1·5 mm.—L. H.

Prevention of Cracks in Steels. C. Butnaru and M. Ponoran. (*Met. Constr. Masini*, 1957, **3**, 23–26). [In Rumanian]. These cracks ~ 0·01 mm wide appear mainly in steels subjected to deformation at high temperatures. Among the many causes contributing to this effect, H_2 is an important factor. The speed of diffusion of H_2 varies with the temperature. Many authors are cited in support of the theory, e.g. Dubovoi who has demonstrated that a steel containing 0·0005% H_2 does not develop cracks whilst steels containing 0·0009% do. Suggestions are offered as to the precautions to be taken in manufacture in order to diminish the formation of these cracks.—L. H.

Residual Stress and Deformation of Bearing Rings after Heat-treatment. T. Hattori. (*Tetsu to Hagane*, 1957, **43**, Mar., 230–231). [In Japanese].—K. E. J.

A Million Pound High-Speed Dynamic Fatigue Test Machine. G. Flynn, jun. and A. F. Underwood. (*Trans. Amer. Soc. Mech. Eng. Preprint*, 1956, 56–A–145, pp. 7). A description of the GMR double-acting hydraulic test machine, with an account of the origin of the project and its principles and operation is given.

Plastic Deformation and Hydrogen Behaviour in the Formation of Flaws in Unalloyed Steel. F. Erdmann-Jesnitzer. (*Arch. Eisenhüttenwesen*, 1957, **28**, May-June, 355–365). To supplement the study of the effect of elastic deformation on H_2 diffusion in the iron lattice, the effect of plastic compression on the discharge of H_2 in soft iron cylinders has been investigated.—L. J. L.

States of Stress. J. O. Predale. (*Machine Design*, 1957, **29**, June 13, 157–162). An outline of new methods for analytical determination of plane states of principal stress and maximum shear stress is presented, with examples.

Summarized Proceedings of a Conference on Stress Analysis—Cranfield, Sept. 1956. H. Fessler. (*Brit. J. Appl. Phys.*, 1957, **8**, Aug., 307–314). **Temperature Distribution in Aircraft Structures and the Influence of Mechanical and Physical Material Properties.** K. L. C. Legg and G. Stevens. Thermal stress efficiencies at different temperatures are indicated for stainless steel and other materials. **Experimental Methods in**

Kinetic Heating Tests. W. H. Horton. **Analysis of Strain Gauge Results under Transient Temperature Conditions.** J. A. G. Holmes. **Strain Distribution in Notched and Cracked Sheets.** V. M. Hickson. A method of making displacement measurements of surface grids is described, using replicas. **Temperature Compensation of Strain Gauges.** R. D. Trumper and A. Fagg. **Digital Recording of Test Data.** J. Arrowsmith. **A Novel Design for a Self-Balancing and Recording Bridge.** W. J. Walker. **Crack Propagation.** A. A. Wells. Prevention of unstable growth and criteria of instability were discussed. **Extensometry with Particular Reference to Mechanical Methods.** R. J. Wilkins. Mainly historical. **Strain Measurement by Mechanical Extensometers.** J. H. Lamble, A. G. Young and E. S. Dahmouch. Various types are described **Some Strain Measuring Techniques for Experiments in Plasticity.** J. Parker and S. S. Gill. Accurate observation of shear, longitudinal and hoop strain of tubular specimens is described. **The Calibration of a Highly Sensitive Extensometer.** F. J. Tranter. Modification of a Lamb extensometer is explained. **The Propagation of Fatigue Damage Measured by Periodic Polishing.** B. K. Foster and T. F. Roylance. Damage tests on a rotating bending specimen were described.

Strain-Ageing as an Explanation of the "Knee" in the Fatigue Curve of Mild Steel. J. C. Levy. (*Metallurgia*, 1957, **56**, Aug., 71–73). Two curves are postulated, one for non-strain-aged material and the other for fully strain-aged material. Transformation from one to the other by ageing during testing may produce the knee in the curve.

The Effect of Crystal Orientation on the Fatigue Strength of Single Crystals of Alpha Iron. M. Hempel, A. Kochendörfer and E. Hillnhagen. (*Arch. Eisenhüttenwesen*, 1957, **28**, July, 417–422). Single crystals of alpha-iron with $\sim 0{\cdot}006\%$ C were produced by the recrystallization process. The fatigue strength of these single crystals and of a polycrystalline soft iron of the same chemical composition, has been determined and plotted in Wöhler curves. At a limiting number of load alternations of 50×10^6, the fatigue strength of the electrolytically polished single crystals of α-iron was $\pm 12{\cdot}5$ Kg per mm².—L. J. L.

New Results Concerning the Importance of Surface Effects on the Initiation of Fatigue Cracks. O. Lissner. (*Jernkont. Ann.*, 1957, **141**, (71, 380–389). [In Swedish]. A quenched and tempered Cr–Ni–Mo steel was used. Interruption of a fatigue test does not influence the life of the test-piece in non-ageing materials. Removal of a thin surface layer considerably increases endurance. Turning repeated 8 times, each time after 30% of ordinary life, gave a total increase of 633%. An increase of fatigue limit due to cold working during the test has been observed. The overstressed layer is removed by the turning and the remaining material is found to have improved fatigue properties.

Chart Gives Ductile Material Endurance Limits. A. B. Carr. (*Machine Design*, 1957, **29**, May 30, 93–95). The equations are given and examples are worked from the chart constructed from them.

Significance of Material Properties in Design for Fatigue Loading. J. Marin. (*Machine Design*, 1957, **29**, Jan, 24, 88–94; Feb. 7, 95–99; Feb. 21, 124–134; Mar., 7, 95–99; Mar. 21, 154–157). A mathematical treatment of static stresses, failure theories, design for stress concentration, fatigue with simple and superimposed stresses and varying amplitude, theories of failure and working stress relations, stress concentration factors and consequences for design, temperature and surface effects is presented. (77 references).

The Endurance Range of Crankshafts and Its Appraisal in Acceptance Tests. A. T. Wuppermann. (*Stahl u. Eisen*, 1957, **77**, Aug. 22, 1117–1122). A report on fatigue tests is given carried out on hammer-forged Diesel engine crankshafts 1·5–4·5 m long weighing 500–2500 kg. Torsion tests were performed on good and faulty pieces. Failures occurred at $40–130 \times 10^6$ cycles at loads of $\pm$ 6–8 kg/mm². Various failures that occurred are described, but there was no relation between the position of a defect and the onset of a fatigue crack. The presence of visible defects had no effect on the endurance range. Proper design of the crankshafts, i.e. the elimination of stress concentration and stress raisers, has a far greater effect than any metallurgical factors.—T. G.

Fatigue of Carbon Steel by the Ultrasonic Flaw Detection Method. H. Yamanouchi and T. Inukai. (*Rep. Castings Res. Lab. Waseda Univ.*, 1956, Oct., 55–58). [In English]. Pulse techniques in the range 2·25–10 Mc/s were used. The values of the ultrasonic attenuation factor in mild steel during fatigue testing vary with repeated stress intensity and stress cycle; they increase gradually in proportion to the stress cycle, showing a transition point on the curve. By ultrasonic wave testing the process of crack development under repeated stress can be followed.

Creep and Recovery. (*Amer. Soc. Metals. Report of Seminar held at the 38th National Metal Congress and Exposition, Cleveland, Oct.* 1956. 1957, pp. 372). **Thermodynamics and Kinetics of Recovery.** M. B. Bever. (14–51). The cold-worked state is reviewed and the energy stored and its release are discussed. (59 references). **Polygonization.** W. R. Hibbard jun. and C. G. Dunn. (52–83). Extensive studies of the annealling of bent crystals are reported and structures shown. **(Discussion,** J. J. Gilman, 79—83). **Mechanism of Annealing in Neutron Irradiated Metals.** T. H. Blewitt, R. R. Coltman, D. K. Holmes and T. S. Noggle. (84–110). Defects produced by irradiation are treated quantitatively and mechanisms and rates of recovery are considered. **Recovery of Mechanical Properties.** E. C. W. Perryman. (111–145). Complete annealing of strain hardening is discussed, mainly in non-ferrous systems. (84 references). **Recovery of Internal Friction and Elastic Constants.** A. S. Nowick. (146–175). Recovery is extremely rapid so that in min after deformation at room temp. large changes have already taken place. Two theories of recovery are discussed. point defects created by deformation may pin the dislocation segments or dislocation rearrangement may take place. (48 references). **The Concept of Creep.** E. N. da C. Andrade. (176–198). **Theory of Creep.** G. Schoeck. (199–226). (71 references). **The Role of the Boundary in Creep Phenomena.** E. R. Parker and J. Washburn. (227–250). **(Discussion,** R. W. Guard, 251–254). **The Spectrum of Activation Energies for Creep.** J. E. Dorn. (255–283). The effects of substructures are particularly considered. **Creep and Fracture.** N. J. Grant and A. R. Chaudhuri. (284–343). (91 references). **Creep of Crystalline Nonmetals.** J. B. Wachtman jun. (344–360). Creep of ceramic oxides, Al_2O_3, MgO and TiO_2, is discussed.

The Behaviour of Heat-Resistant Steels in Long-Term Creep Tests at 500–700° C. Introduction. K. Richard. (*Arch. Eisenhüttenwesen*, 1957, **28**, May-June, 245–246). A general introduction is given to reports of tests under the auspices of the Fachgemeinschaft Kraftmaschinen. (Engine Manufacturers' Association), the Verein Deutscher Eisenhüttenleute the Vereinigung de Grosskesselbesitzer (Boiler Owners' Association) and the Wasserrohrkesselverbond (Water Tube Boilers Association) on 23 ferritic steels, 12 austenitic steels, and low-iron metal alloys at temperatures of 500, 550, 600, 650, and 700° C over extended periods in experimental furnaces capable of testing 1000 samples simultaneously. **Part I. Experimental Apparatus and Methods.** H. Reiner. (*Arch. Eisenhüttenwesen*, 1957, **28**, May-June, 247–252). For tests at 500, 550, and 600° C, 25 or 27 sets consisting of 8 specimens each are placed in the oven. Tests at 650° C are carried out in ovens accommodating one set of 8 specimens, and at 700° C in apparatus taking 12 sets of 4 specimens each. Temperature can be kept constant in all apparatus. Elongation is measured in specimens that are removed at regular intervals and allowed to cool. Accuracy of measurement for a permanent elongation of 1% is $\pm 1{\cdot}5\%$. **Part II. Methods of Evaluation.** G. Bandel and H. Gravenhorst. (253–258). Practical examples are given to illustrate the graphs used in evaluating the tests. Results are compared with those obtained for time and temperature by other methods, including those described by F. R. Larson and J. Miller. They were found to be suitable for interpolation, but, owing to the wide scatter, extrapolation can only be applied, in all methods, to limited ranges of time, temperature, stress, and elongation. **Part III. Results of Long-Time Creep Tests on Ferritic Tube Steels.** E. Jahn. (259–267). Elastic limits and creep strengths of ferritic tube steels have been determined over periods of up to 50,000 hours at temperatures of 500, 550, and 600° C. **Part IV. Results of Long-Time Creep Tests of Ferritic Machine-Construction Steels.** H. Holdt and P. Grün. (269–285). The steels tested had Cr contents up to 13% Mo contents up to 2%, and V contents up to 0·6%. The effects of Co (up to 2%), Ni (up to 1·2%), and W (up to 0·5%) on the long-term high-temperature characteristics of these steels were also investigated. **Part V. Results of Long-Term Creep Tests on Austenitic Steels and Alloys.** K. Bungardt. (287–304). Results are reported of tests on Cr–Ni steels,

Cr–Mn steels, Cr–Co–Ni–Fe alloys, and Ni alloys. **Part VI. Metallurgical Studies of Austenitic and Ferritic Steels after Long-Time Creep Tests.** A. Krisch. (305–310). Specimens of three austenitic steels (X8 CrNiTi 16 13, X8 CrNiMoNb 16 13 and X8 CrNiNb 16 13) and of two ferritic steels, a Mo steel, and a Cr–Mo–V steel (24 CrMoV 5 5) were isolated by electrolysis after test, and the isolates were studied by microanalysis and radiography. In all these steels, the isolated carbides were found to have been changed by the tests. **Part VII. Dynamic Stress Tests at 500–650° C on Ferritic and Austenitic Steels.** M. Hempel. (311–316). Alternating compression and tension tests were made on smooth and notched specimens of ferritic steel (24 CrMoV 5 5) and austenitic steel (X8 CrNiMoNb 15 15) at room temperature and temperatures from 500 to 650° C. **Part VIII. Some Preliminary Conclusions.** R. Schinn and W. Ruttmann. (317–323). It is the object of these co-operative tests to provide reliable data for the assessment of heat-resistant steels. This requires knowledge of the creep characteristics of the steels at practicable temperatures for periods up to 100,000 hours. The creep characteristics of a steel differ according to treatment and temperature. From the results obtained so far it is impossible to assume that the various groups of steels have common creep characteristics.

The Conversion of Long-Time Creep Figures to Other Temperatures. A. Krisch and W. Wepner. (*Arch. Eisenhüttenwesen*, 1957, **28**, May-June, 339–344). The experimentally determined creep curves for 19 ferritic and 19 austenitic steels at 2 or more temperatures have been compared by the method according to F. R. Larson and J. Miller. Agreement in most cases was poor, and it was therefore impossible to draw a "master curve" for these steels. It was however possible to calculate the experimentally known creep strength for 10,000 hours with an accuracy of $\pm$ 10%, if creep data for a temperature 50° C higher were available.—L. J. L.

On the Method of Extrapolation of Creep Test Data. V. S. Ivanova. (*U.K. Atomic Energy Authority*, IGRL–T/R–21. 1957, pp. 7. Translated from *Teploenergetika* 1956, (1), 26–28). An exponential equation is shown to be more accurate than the usual power series.

100,000 Hour's Creep Tests at 500° C on Steels of Various Composition. A. Thum and K. Richard. (*Arch. Eisenhüttenwesen*, 1957, **28**, May-June, 325–338). Unalloyed steels with 0·02 to 0·35% C, ferritic Mn, Cr, Mo, Cr–Mo, Cr–Ni–Mo, Cr–V, Cr–Mo–V, Ti, Cr–Ti, and Nb steels, and austenitic Cr–Ni steels have been investigated for periods of up to 140,000 h.—L. J. L.

Special Phenomena in Creep Research. W. Stauffer and A. Keller. (*Schweiz. Arch. Wiss. Techn.*, 1956, **22**, Dec., 389–402). The creep curve obtained over a long period may be considerably different from the classical form. Linear and log-log plotting are both useful but even the latter plots of creep rupture strength and creep limit may differ. Embrittlement indicated by stress rupture tests may differ from that obtained in notched bar impact tests.

Creep Properties of Austenitic Nickel–Chromium Steels Containing Niobium. W. H. Bailey, M. G. Gemmill, H. W. Kirkby, J. D. Murray, E. A. Jenkinson and A. I. Smith. (*Chartered Mech. Eng.*, 1957, **4**, Sept., 348–349). A summary only is given of work at the N.P.L., with log time, stress and temperature plots, for 18–12–1 tubes for superheaters.

Testing Machine for Short-Time Creep and Stress-Rupture Testing at 2000–2500° C. M. C. Smith, D. M. Olson and H. L. Brown. (*Rev. Sci. Instruments*, 1957, **28**, July, 543–547). Loads up to 100,000 psi can be applied. The range can be extended by minor modifications.

Problems of Combined Creep and Fatigue Design. A. J. Kennedy. (*Engineer*, 1957, **204**, Sept. 27, 444–447). A discussion is presented of the interaction of the processes of deformation and fatigue, particularly deformation by creep, so far as it is known, in view of the difficulty of making combined tests and the limited value of tests on either in isolation. Solid diagrams showing the relationships are developed, but the need for more data and of computational methods of handling them are stressed.

The Dangers of Cast Iron Pulleys. (*P.A.C.T.*, 1957, **8**, April, 129–131). Cast iron pulleys break in service for several reasons. Sometimes they have faults, such as minute cracks, which are only visible on exhaustive examination. Cracks may arise from tensions during casting due to poor design or from forcing of the pulley on the spindle. These faults rarely appear immediately and hence pulleys taken from second hand depots should be throughly examined before use. Another cause of breakage is the use of the pulley at too high a revolution speed. Five typical accidents, some fatal, due to pulley-breaking are described. It is concluded that there should be strict supervision of the use of pulleys. All second hand ones should undergo minute examination before putting into use again. Pulleys should not be used at higher speeds than they are designed for. The setting up of pulleys and their operation should be limited to qualified personnel.

Behaviour of R-65 Rails in Service. N. P. Kondakov. (*Stal'*, 1957, (8), 722–724). A comparison is made of R-65 (110 lb/yard) and R-50 (85 lb/yard) rails in service on one of the most used sections of the Trans-Siberian railway. The heavy rails performed better and defects appearing are related to traffic tonnages. After 370×10^6 t of traffic the rate of scrapping was four times that after 100×10^6 t. Flaking of the head accounted for 45% of the heavier rails scrapped and 36·74% of the lighter rails.

Hardness of Spheroidal Graphite Cast Iron Consisting of Various Amounts of Ferrite. T. Kusakawa and T. Kasai. (*Rep. Castings Res. Lab. Waseda Univ.*, 1956, Oct., 7–12). [In English]. The hardness of spheroidal graphite cast iron having a ferrite phase is at first reduced and then slightly increased with increase of Si content in the range 1–4·5%, while that of annealed specimens is increased. That of Mg-treated, spheroidal graphite iron is 1·5–2 times greater than that of flake graphite iron. The hardness of the ferrite phase in the former is slightly higher than that in the latter.—K. E. J.

Errors in Reading Diameters in the Brinell Hardness Test. C. Chaussin. (*Mét. Constr. Mécan.*, 1957, **89**, May, 477). There are two main errors involved in the Brinell hardness test: the diameter of the imprint and the diameter of the ball. The influence of the latter is shown to be comparatively small.

Contribution to the Study of Ageing in Mild Steel. E. Herzog, V. Chentre, J. Boyet and M. Hugo. (*Rev. Mét.* 1957, **54**, May, 337–353). The application of micro tensile tests and electrical resistivity measurements between 20° and 300° C to the study of ageing in mild steel is described. The steels studied have been deoxidized with:— C + Mn, Si + Al, Si + Al + Ti with small residual percentages and in several steels with 1% Ti or 1% Al. Al is shown to slow down the diffusion of N and C atoms during the movement of dislocations between 20° and 300° C whereas Ti fixes the N_2 before the C. Transition temperatures after 10% cold working and artificial ageing at 250° C are 50° C lower for spheroidal carbides obtained by quenching and tempering than after an annealing of the pearlite.—B. G. B.

50 Years' Age Hardening in Research and Practice. G. Wassermann. (*Z. Metallkunde*, 1957, **48**, May, 223–231). A survey is made of the development of the theory and practice of age-hardening. Most of the paper deals with aluminium alloys, but reference is made to recent theories dealing with the ageing of steel.—L. D. H.

The Effect of Electrolytic Carbon Transfer on the Ageing of Alpha Iron. F. Erdmann-Jesnitzer and K. Ouvrier. (*Arch. Eisenhüttenwesen*, 1957, **28**, July, 423–431). In a transfer experiment at about 825°, preferential carbon diffusion towards the cathode was achieved, which may be interpreted as a qualitative demonstration of the presence of positive carbon ions in alpha-iron. The effect of d.c. on the rate of change in hardness and resistance of Armco iron after quenching was studied. There was qualitative evidence that ageing is accelerated at 80° C.—L. J. L.

The Tendency of Steels to Brittle Fracture in Relation to [Multi-Axial] Stress and Temperature. A. Kochendörfer and H. Scholl. (*Stahl u. Eisen*, 1957, **77**, July 25, 1006–1018). The brittle fracture behaviour of basic Bessemer and O.H. steels was studied on notched test pieces in static bending tests in the range from room temperature to liq. N_2 temperature. The authors introduce a multi-axial index. κ, defined in terms of the comparison stress in the shape-altering energy hypothesis. The results are presented in three-dimensional diagrams in which yield stress and U.T.S. are plotted as a function of κ and the temperature. The diagrams show directly the brittle-fracture temperature is also plotted against κ. The results are discussed in detail with special reference to applications.—T. G.

The Influence of C, Mn, Si and Al on the Displacement of the Cold-Brittleness Transition Temperature of Steels. Kh. Levinzon. (*Stal'*, 1957, (8), 747–748).

Wear Experiments on Railway Brake Shoes. E. Füle. (*Kohászati Lapok*, 1953, **8**, *Ontöde*, Jan., 6–12; Feb., 39–44;

March 56–62). The author describes Hungarian full-scale wear experiments on grey iron railway brake shoes. A logarithmic correlation was found between the wear and Brinell hardness and this relationship was graphically plotted. A Brinell hardness more than 240 HB is unfavourable, due to the cementite in the structure.—P. K.

Severe Abrasions? Try White or Chilled Cast Iron. J. H. Culling and J. F. Wallace. (*Materials in Design Engineering*, 1957, **46**, Aug., 99–101). A chapter from a forthcoming book. Structure, properties and uses are outlined with illustrations of typical parts.

Cumulative Damage in Fatigue—A Design Method Based on the *S–N* Curve. J. C. Levy. (*J. Roy. Aeronaut. Soc.*, 1957, **61**, July, 485–491). A safe design method for a two-stress level system is suggested by a method of plotting the results of fatigue tests with alternating different stress amplitudes. The method is checked against a wide range of experimental results. Extensions to multiple stress levels are indicated.

Contribution Towards the Rapid Determination of the Limit of Fatigue. I. Schaechter. (*Met. Constr. Masini*, 1957, **9**, (1), 35–40). [In Rumanian]. Most of the methods determining the limit of fatigue measure the stresses which at the critical value are followed by irreversible transformations in the metals. This critical value depends on the respective parameters. The Prot method, based on a different principle, is examined and then, after consideration of the fatigue mechanism, some arguments are considered regarding the possibility of evolving a general method for the rapid determination of fatigue limit.—L. H.

Method of Evaluating the Tendency of Materials to Delayed Break-Down. T. K. Zilova, N. I. Demina and Ya. B. Fridman. (*Zavodskaya Laboratoriya*, 1956, **22**, (8), 967–972). [In Russian]. The redistribution of energy produced by localization of the deformed region or by local fracture in a closed stressed system has been studied: factors known to be conducive to delayed rupture were found to promote localization of deformation or rupture. The reasons have been examined which facilitate delayed rupture at high homologous temperatures and of the special features of the reproduction of delayed rupture at low homologous temperatures. Laboratory methods are proposed for testing materials for tendency to delayed rupture at such temperatures. A coefficient is advanced for liability to delayed rupture which is the ratio of the short-term breaking load to the breaking load obtained in prolonged tests: its application to two steels is shown.—S. K.

Fatigue of Metals During Contact Friction. V. S. Ivanova and I. A. Oding. (*Izvest. Akad. Nauk, S.S.S.R., Otdelenie Tekn. Nauk*, 1957, (1), 95–102). [In Russian]. The process of fatigue during contact friction was investigated on steel specimens KhN3M and KhN4M (similar in composition except for Ni which was 2·55 and 3·70% respectively). Chemical composition and mechanical properties of steels are given. Fatigue tests were carried out on a special apparatus in which specimens can be tested during symmetrical bending in air and H_2 atmospheres. The apparatus and experimental procedure are described. It was established that there is no decrease in the fatigue limit of CrNiMo steel when tested in an atmosphere of H_2. It was shown by tests of up to 250 million cycles that in the presence of contact friction a continuous decrease in cyclic strength is observed in both air and H_2. Treatment of experimental data by Weibull's method (*Trans. of the Roy. Inst. of Technology, Stockholm*, No. 27, 1949) indicated that the fatigue limit of Cr–Ni–Mo steel under conditions of contact friction is equal to zero or possesses a very low value. A decrease in the fatigue limit under conditions of contact friction is explained by an electro-erosion process taking place under the influence of thermoelectric current, formed as a result of friction and pulsating in its value due to changes in the contact resistance. The action of electro-erosion can be inhibited or altogether removed and thus the fatigue limit increased by changing the direction of thermoelectric current. This can be done either by a suitable choice of contact material or by passing a counter-current. The mechanism of fatigue failure under conditions of contact friction can be considered as the formation of vacancies in the crystal lattice during the transfer of metal during the electro-erosion process.

Reports on Fatigue Failures. Commission XIII. Inst. internat. de la Soudure. (*Soudage et Techniques Connexes*, 1957. July-Aug., 255–263; *Revue Soudure*, 1957, **13**, (1), 60–66). This report is a critical survey of service failures in several welded structures. Discussion is centred round the stresses in the damaged area, failure characteristics, composition and cause of failures. Various failures in service are reported: The breakage of a stainless steel mixer arm, of a welded press frame, of a stainless steel washing machine axle and the crossbar of a tank wagon originating at a weld.—B. P.

Fatigue Limit and Size Effect in the Case of Alternating Tension and Compression. A. Pasetti. (*Met. Ital.*, 1957, **49**, July, 523–530). [In Italian]. The principal theories dealing with size effect are briefly discussed and a series of experimental push-pull tests on plain and notched specimens of different sizes is described in detail. The author puts forward a theory which makes it possible to foresee within reasonable limits the fatigue limit for large parts. (10 references.)—M. D. J. B.

The Effect of Residual Austenite in Carburized Layers on Behaviour under Alternating Stress. B. Přenosil. (*Hutnické Listy*, 1957, **12**, (8), 704–711). Comparison of endurance limits of carburized bars with and without austenite removal by sub-zero treatment was made. From this and earlier work on carbonitrided layers it appears that endurance limit is increased where fatigue fracture would start at the surface if austenite is removed, that where the fracture would start underneath the hardened layer the limit is decreased, but to a relatively small degree. Explanations in terms of internal stresses are offered.

Intergranular and Intragranular Character of the Failure of Armco-Iron in Fatigue. V. S. Ivanova. (*Doklady Akad. Nauk, S.S.S.R.*, 1957, **114**, (3), 537–540). [In Russian]. Sample plates of Armco-iron, annealed for two hours at 950° in a vacuum, polished and etched, were tested for fatigue on bending in an electro-magnetic apparatus. Functional relations between the frequency of cycles and tension is shown in diagrams. Microstructural study showed that the failure occurs mainly between the grains above the flow limit and in the bodies of the grains below this limit. The results obtained are discussed.—S. I. T.

The Influence of Materials Used for Bushings and Bearings on the Fatigue Life of Their Shafts and Axles. I. V. Kudryavtzev. (*Vestnik Mashinostroenniya*, 1956, **36**, (7), 10–15). [In Russian]. Extensive experiments, mainly by the magnetic suspension method, are described to ascertain the limit of fatigue of metals with various characteristics. The specimens have been submitted to stresses of up to 10^8 cycles if necessary before fatigue cracks appeared. The findings of these experiments seem to contradict existing references which connect the lowering of the resistance to fatigue with a decrease in the hardness of the materials of the bushings.

Mechanical Properties of Steels after Saturation of their Surface with Chrome. G. N. Dubinin. (*Vestnik Mashinostroenniya*, 1956, **36**, (10), 56–58). [In Russian]. Experiments conducted with this end in view have shown, in the opinion of the author, that the observed increase in the resistance to fatigue of steels at elevated temperatures is not so much connected with the diffusion effect of the mobility of the atoms, which might counteract any surface imperfections leading to fatigue cracks, as to a general increase in the elasticity of the metals so treated, thus improving their resistance to fatigue.—L. H.

Theories of Metallic Creep. J. M. Summerton. (*J. B'ham Met. Soc.*, 1957, **37**, Sept., 537–552. A prize essay.

Studies on the Creep Rupture of Steel by Hot-Stage Microscope Observation. I. T. Bada. (*Tetsu to Hagane*, 1957, **43**, Mar., 348–350). [In Japanese]. Details are given of an arrangement whereby specimens heated *in vacuo* may be observed microscopically. Results for V-Notch specimens are given for temperatures between 500° and 650° C, and rupture is classified as transcrystalline or intercrystalline.

Studies on Creep Properties of Chromium-Molybdenum Steels. I. Effect of Deoxidation Practice. S. Terai. (*Tetsu to Hagane*, 1957, **43**, Mar., 318–320). [In Japanese]. Creep curves at 600° C and 10 kg/mm² are given for 1 Cr 0·5 Mo steels with various Al additions up to 400 g/t, and a relationship is indicated between creep rate and soluble Al content. Creep curves are also given for various annealing temperatures between 900° and 1200° C.—K. E. J.

Factors Influencing the Cracking of Rails. W. Grobicki. (*Hutnik*, 1956, **23**, Dec., 450–453). [In Polish]. Some of

the causes discussed of rail cracking are: internal faults in the material produced during the process of rolling; internal stresses developed during careless cooling of finished rails; poor maintenance of the track; stresses derived from changes in the ambient temperature; stresses caused by creep, by uneven load of rolling stock, frost and metal fatigue.

Determination of Hardness by the POLDI Comparative Method. J. J. Fernández Fernández. (*Met. Elect.*, 1957, **21**, Apr., 64–66). A method of indentation using a standard simultaneously is described and correlated with Brinell figure.

High Temperature-Resistant Hardness Testers for Metals Heated in Vacuum up to 1300° C. M. G. Lozinskii and M. B. Guterman. (*Zavodskaya Laboratorya*, 1956, **22**, (11), 1358–1363). [In Russian]. The method of measuring the rigidity of metals in high temperatures with indentators, under load, is widely used. For the extension of the temperature range to 1300° *in vacuo* the experiments described showed that the pyramid shaped diamonds become blunted and are not reliable. New materials have been investigated and the most promising is a synthetic corundum (artificial sapphire). The experiments have been carried out by the Scientific Machine Institute of the Soviet Science Academy.—L. H.

Testing Spheres for Hardness and Absence of Cracks by a Bouncing Method. V. K. Grigorovich. (*Zavodskaya Laboratoriya*, 1956, **22**, (8), 973–979). [In Russian]. An account is given of a study of the bouncing of steel bearing balls from a hardened steel plate which showed that this could be used as an objective quality-control method suitable for 100% testing. It was found that a hardness < 58 R_C or the presence of cracks lead to appreciable reduction of bounce. An automatic testing machine is described in which the balls bounce repeatedly on hardened steel plates: balls which are cracked or whose hardness is < 58 R_C are removed. The machine has undergone successful tests.—S. K.

On the Effect of Hydrostatic Pressure on the Hardness of Carbon Steels. V. A. Gladkovskii. (*Fizika Metallov i Metallovedenie*, 1956, **3**, (1), 183–184). [In Russian]. The composition of the steel was 0·26% C and 0·5% Mn. The hardness of this steel seems to increase linearly with the pressure.—L. H.

The Relation of Temperature to Hardness in Steels. A. I. Betaneli. (*Fizika Metallov i Metallovedenie*, 1956, **3**, (3), 540–546). [In Russian]. The investigations carried out by the pressure method have led to the deduction of a mathematical formula for the relation between hardness and temperature, which in ordinary terms could be explained by the fact that this relation is predetermined by the reciprocal interaction of the strengthening and weakening forces and by the conditions at the grain boundaries.—L. H.

Influences of Various Elements on High-Carbon Chromium Steel. I. Hardenability and As-quenched Hardness. S. Kawaguchi. (*Tetsu to Hagane*, 1957, **43**, Mar., 277–278). [In Japanese]. Results show the effects of carbon content on the Jominy hardenability of high-carbon 1·7% Cr steel, and of Cr content on the hardenability of 0·8% C low-Cr steel.

Determination of the Hardenability of Chromium–Manganese Tool Steel. V. V. Polovnikov. (*Zavodskaya Laboratoriya*, 1956, **22**, (5), 565–567). [In Russian]. After a brief discussion of hardenability criteria, determinations on Cr–Mn tool steels are considered which were based on the measurement of the hardness of test pieces subjected to hardening after various isothermal heat treatments. Optimal sizes for the test pieces were found in preliminary experiments. All the experimental heats dealt with contained about 1% C, were relatively free from non-metallic inclusions and had very small austenite grain size. It was found that with Mn contents increased to 1% the effect of elevations of the Cr content on austenite stability increased; the presence of over 1% Mn increases austenite stability for the same additions of Cr.—S. K.

Applicability of Different Variants of Face Testing for Hardenability. A. A. Gol'denberg. (*Zavodskaya Laboratoriya*, 1956, **22**, (9), 1063–1065). [In Russian]. The applicability of various types of hardenability-test procedures involving the rapid cooling of one face of the test piece is discussed on the basis of literature data and some original work.—S. K.

Ageing of Medium-Carbon Killed Steel. T. Kaneda. (*Tetsu to Hagane*, 1957, **43**, 398–400). [In Japanese]. For specimens of given composition and austenitic grain size, changes in ageing value after prestraining 5% in tension and ageing at room temperature, 100° C and 230° C are given. The variation of N_2 combined as AlN after various heat-treatments is also given.—K. E. J.

Effect of Conditions of Deformation on the Susceptibility of Steels to Mechanical Ageing. M. I. Kurmanov. (*Fizika Metallov i Metallovedenie*, 1956, **3**, (2), 332–340). [In Russian]. The dynamic deformation taking place during mechanical operations and during the lowering of temperature, does not increase the tendency to ageing, but on the contrary, diminishes it. As to the conditions of eliminating ageing in steels, attention is drawn to their chemical composition and especially to the free N_2 and O_2 content.—L. H.

Method for Determining the Tendency to Deformation by Ageing of Constructional Steels. K. M. Pogodina-Alekseeva. (*Zavodskaya Laboratoriya*, 1955, **21**, (9), 1104–1106). [In Russian]. The recommended procedure for the tests is GOST 399–41 which is explained in great detail. A few actual tests are described as examples and the results obtained are tabulated.—L. H.

On a Method of Determining Temper Brittleness of Steel. Yu. Ya. Voloshenko-Klimovitskii. (*Izvest. Akad. Nauk, S.S.S.R., Otdelenie Tekh. Nauk.*, 1956, (11), 98–100). [In Russian]. The possibility of evaluating the plasticity of metals from oscillograph records of load-time, obtained during impact stretching of cylindrical specimens with a ring notch was demonstrated on 30-KhGSA steel specimens. The method described can be used for testing temper-brittleness of metals.—V. G.

Structure Peculiarities of Constructional Steels in the State of Reversible Temper Brittleness. S. F. Yur'ef and Z. I. Kusnitsina. (*Fizika Metallov i Metallovedenie*, 1956, **3**, (2). **I. Micro-structure Analysis**, (282–291); **II. Microscopical Investigation of Fractures**, (292–298). Investigations based on the appearance of fractures are bound to contain a subjective and incomplete background of qualitative observation, since from purely geometrical considerations it is impossible to say unambiguously if the crack follows the boundaries of the austenite grains or passes through them. The authors aim at a strictly objective method of investigating the tendency of steels to develop temper brittleness by determining the micro-structure of the region in which damage develops, and in a microscopical supplementary study, by examining the fracture by means of a 400 × binocular microscope. These exhaustive investigations are described in detail.—L. H.

Study of the Cold Brittleness of Plain Carbon Steel. II. Directionality of Impact Value in Hot Rolled Steel. S. Nakanishi. (*Tetsu to Hagane*, 1957, **43**, Mar., 359–361). [In Japanese]. Curves are given for impact value against temperature for 0·16% C steel, furnace-cooled and air-cooled. Impact values are given for the same samples at angular positions between 0° and 90° to the rolling direction. Impact value-temperature curves generally are analysed in terms of crack initiation and propagation.—K. E. J.

Influence of Thermo-Mechanical Treatment on the Cold-Brittleness of Structural Alloy Steels. E. N. Sokolov. (*Fizika Metallov i Metallovedenie*, 1956, **3**, (1), 79–82). [In Russian]. The thermomechanical treatment refers here to the combination of hot plastic deformation in the austenite state with the hardening which follows. The changes which ensue in the austenite and in the nascent martensite hamper the development of brittleness during tempering.—L. H.

Determination of the Tendency to Cold-Brittleness of Structural Ferritic Steels in Accordance with the Data from Tensile Tests on Smooth Specimens. P. O. Pashkov and V. A. Bratukhina. (*Fizika Metallov i Metallovedenie*, 1956, **3**, (1), 162–171). [In Russian]. The possibility of calculating the tendency of ferritic steels to cold-brittleness was established. Temperature brittleness can be estimated by the relative fall in the concentrated portion of plasticity (meaning probably the deformed region of the specimen) as determined by the fracture at low temperature (— 196° C) and at room temperature. The correlation between the critical temperature of brittleness according to N. N. Davidenko, and the coefficient of temper brittleness during stresses, was also established.—L. H.

Results of Some Brittle Fracture Tests from the Point of View of the Fabricator. F. Hebrant, H. Louis, W. Soete and A. Vinckier. (*Rev. Soudure*, 1957, **13**, (1), 31–48). Discs and cross-shaped plates were welded, as being typical

of such constructions, and submitted to brittle fracture tests. The cracks produced by impact at the centres of the discs and by tension in two directions at right angles of the plates are shown and described.

Studies on Cylinder Liners of High-speed Diesel Engines. T. Nakajo. (*Tetsu to Hagane*, 1957, **43**, Mar., 250–251). [In Japanese]. Wear results are given for tests up to 800 h in three different engines of seven types of steel liners (compositions, hardnesses and heat-treatments detailed).

Friction As A Resistance To Shear Of Thin Surface Layers of Solids. G. J. Epifanov. (*Doklady Akad. Nauk, S.S.S.R.*, 1957, **114**, (4), 764–767). [In Russian]. Special methods of study of friction were applied to Fe, Al, Cu, and other metals The apparatus used had a hemispherical steel slide situated behind the cutting tool. This allowed measurement of the power of cutting and the power of friction. Adhesion power was also measured by the introduction of a small amount of lubricant. It is concluded that if the dimensions of the area of shear are correctly evaluated, the specific power of friction corresponds to the strength of the surface layer of the metal.—S. I. T.

On the Jump in Frictional Force on Stopping. D. M. Tolstoi and Pan' Bin'-Yao. (*Doklady Akad. Nauk, S.S.S.R.*, 1957, **114**, (6), 1231–1234). [In Russian]. A new apparatus for observation of the friction of steel against steel is described and the results of measurement of the difference of static and dynamic friction on stopping, are given and discussed.

The Temperature Relation of the Internal Friction of Some Pure Metals. V. S. Postnikov. (*Fizika Metallov i Metallovedenie*, 1957, **4**, (2), 344–351). [In Russian]. The relation between the temperature and the internal friction can be explained on the basis of the relaxation theory of the phenomena occurring during cold work. The contamination of the pure metals by admixtures leads to a lowering of the level of internal friction at sufficiently high temperatures.—I. H.

Anomalous Behaviour of some Steel Bars Due to Surface Defects. (*Brit. Eng. Boiler Elec. Ins. Techn. Rep.*, 1957, **3**, 158–160). Mild steel bars breaking in a brittle manner in tensile tests but bending through 180° without cracking were found to have cracking defects at some of the corners. The notched bar test would have revealed the fault but is not usually called for in specifications.

Electric Extensometer Strip in the Testing of Materials. W. Köhler. (*Werkstoffe Korrosion*, 1957, **8**, July, 389–393). Use in tensile testing with single and multiple stress in the elastic range is described. Other uses are mentioned.

An Exact Solution for the Stress Distribution in Notches with given Values of Depth and Angle. H. Neuber. (*Forsch. Ingenieurwesens*, 1957, **23**, (1/2), 9–10). A mathematical treatment for the notch factor in notched brass is given. A simple expression for the particular case of very small radii of curvature in notches of any depth is derived. A comparison with a previous investigation indicates the validity of this treatment.—J. R. P.

Flaring Test and Flattening Test of Steel Tubes. T. Okamoto. (*Sumitomo Metals*, 1957, **9**, Jan., 21–30). [In Japanese]. Investigations were made of the physical significance of these two tests, particularly as regards tube size and tool angle. The max. expansion in the flaring test increases with the thickness of tube, and can be explained in terms of reductions; the influence of tool angle is slight. In the flattening test, the minimum distance apart of plates (in terms of wall thickness) at which cracks begin is increased as wall thickness decreases. The flattening test according to J.I.S. or A.S.T.M. specifications is better than that according to Lloyds or J.E.S.—K. E. J.

Slit Hollow Cylinder and Profiled Bars with Rounded Corners under Torsion. D. Tiedemann. (*Forsch. Ingenieurwesens*, 1957, **23**, (1/2), 27–28). By analogy with membranes the stress concentration in metal fillets of twisted and flat sheet profiles is calculated. Comparison with previous calculations for different profiles indicates the influence of additional material concentrated on the outer corners.—J. R. P.

Brittle Fracture of Mild Steel in Torsion. J. B. Hunt. (*Engineering*, 1957, **184**, Aug. 9, 173–174). Impact tests were carried out on specimens in torsion at temperatures of + 100° to −195° C. Brittle fracture occurred only at the lowest temperatures. A uniform elasto-plastic twist exists and becomes a maximum when the overall ductility begins to decrease.

The Notch-Impact Test. K. Rühl. (*Schweissen u. Schneiden*, 1957, **9**, March, 83–90). The notch-impact test is described in detail. The behaviour of the Charpy test sample and other notch geometry is discussed. The requirements and applications of the notch impact test are considered.

Effect of Carbon and Manganese on Properties of Constructional Steels For Dynamic Loading Applications. R. D. Engquist. (*Amer. Found. Soc. Preprint*, 1957, No. 57–71, pp. 5). An analysis of service failures in carbon steel railway truck castings indicated that an improvement in impact properties at low temperatures was desirable. Results are given to show that this can be achieved by raising the Mn content and lowering the carbon content of the steel. The modified alloy is shown to have an improved resistance to hot tearing, a better hardenability, and to be readily weldable.

Considerations on the Intelligent Use of Notch-Impact Data in the Quality Control with Respect to Brittle Fracture and Weldability of Standard Structural Steels. H. Kornfeld. (*Stahl u. Eisen*, 1957, **77**, June 13, 792–798). The author suggests basing weldability and the tendency of a steel to brittle fracture on the transition temperature D_u of the notch impact/temperature curve. D_u is that temperature at which the temperature curves of the mean relative notch impact toughness $\overline{K}_r(D)$ and the relative area of crystalline structure $\overline{F}_{tr}$ intersect, i.e. $\overline{K}_r(D_u) = \overline{F}_{tr}(D_u)$. However, $\overline{K}_r(D_u)$ and $\overline{F}_{tr}(D_u)$ depend markedly on the shape of the test piece. The author found for Charpy test pieces a value of about 55% and for DVM test pieces about 65%. The validity of the equation and the values quoted were disputed in the discussion.—T. G.

The Effect of Segregation, Cold Working, and Ageing on the Notch-Impact Sensitivity of Rimming Mild Steel. H. Schenk and E. Schmidtmann. (*Stahl u. Eisen*, 1957, **77**, June 13, 784–791). Brittle fracture of various structural steels including basic Bessemer and O.H. steels depends on the quantity and degree of dispersion of alloying elements or impurities as was shown by notch impact/temperature curves made on samples taken from various parts of ingots, blooms, or slabs. The effects of P and of insoluble impurities were specially studied. The presence of insoluble impurities are attributed mainly to O and S. The degree of dispersion and the mode of segregation, e.g. at the grain boundaries or within the grains can be modified by heat-treatment. Subsequent cold working or ageing affects the notch impact/temperature curve of the steels.—T. G.

The Work Hardening of Steel. G. E. Tummers. (*Metalen*, 1957, **12**, May 15, 166–8). [In Dutch]. Attention is called to the fact that results of notched bar tests on steel before and after work hardening at room temperature give no complete indication of the suitability of the steel for any particular purpose, especially if the tests do not take into account the ultimate working temperature. It is essential to ascertain the transition temperature before and after hardening and then conduct the notched bar tests as a function of the temperature.—F. B. H.

Influence of Work Hardening of the Edges of Cold-Rolled Transformer Steel on Electromagnetic Properties. A. I. Belyakov. (*Stal'*, 1957, (2), 185–187). [In Russian]. An investigation of the effect of work hardening produced during cutting and of subsequent heat treatment on the electromagnetic properties of cold-rolled transformer steel is described.—S. K.

Fatigue Tests. M. H. de Leiris. (*Soudage Techn. Connexes*, 1956, **10**, Sept.-Oct., 274–275). A report by Commission XIII of the Institut Internat. de la Soudure.

Metal Fatigue at High Frequency. E. A. Neppiras. (*Proc. Phys. Soc.*, 1957, **70B**, April 1, 393–401). Apparatus using a transducer is described.

Component Fatigue Analysis for Maintenance. R. J. Laux. (*Mech. Eng.*, 1957, **79**, July, 656–658). Fatigue failure occurs with loads in excess of the endurance limit which is either pulsating or reversing. Removal of either (by preloading, balancing etc.) will prevent failure of threaded or other small machine parts, and methods are discussed.

Fatigue Testing of Cast Iron. G. Köves. (*Kohászati Lapok*, 1956, **11**, (8), Ontöde, 182–185). The neck of a paper mill drying roll fractured after 70 years service. The comparison of the fatigue testing results and internal stresses determined by X-ray examination in the original condition and after stress relieving appears to show the fatigued

condition of the grey casting caused by the deformation of the crystal lattices. The applied stress-relieving treatment did not alter the original structure and mechanical properties.

The Effect of Size and Notch Sensitivity on Fatigue Characteristics of Two Metallic Materials. Part I. Aluminium Alloy 75S-T. Part II. SAE 4340 Steel. H. F. Moore, T. J. Dolan and B. C. Hanley. (*PB* 120371. *D.S.I.R., T.I.D.U. List* 800, 1946, pp. 160).

Fatigue Failure of a Metal-sprayed Crankshaft. (*Brit. Eng. Boiler Elec. Ins. Techn. Rep.*, 1957, **3,** 125–127). Cracking appeared to have started at a machined groove, the adhesion of the sprayed metal was poor.

Fatigue Failure of a Chromium-Plated Crankshaft. (*Brit. Eng. Boiler Elec. Ins. Techn. Rep.*, 1957, **3,** 120–124). A 3-cylinder oil engine crankshaft failure is described. Crankpins were ground and Cr plated during overhaul and grooving and cracking occurred.

Effect of Residual Stresses upon the Fatigue Strength of Shafts Carrying Tight Sleeves. I. V. Kudryavtsev and N. M. Savvina. (*Metallovedenie i Obrabotka Metallov*, 1955, **1,** (5), 17–23). Surface strain hardening greatly increases endurance limit of such shafts and axles and this is due to residual compressive stresses and not to surface hardness. Other treatments producing residual stresses are also effective. Torsional strain hardening was used in the experiments and equations for calculation of stresses are given.

New Techniques Aid Metallurgical Research at the N.P.L. E. I. Brimelow. (*Metallurgia*, 1957, **56,** July, 9–12). A review based on Open Day exhibits. Brittleness, creep and fatigue are outlined.

The Effect of Some Factors on the High-Temperature Relaxation of Metals. L. Čížek. (*Hutnické Listy*, 1957, **12,** (4), 335–342). [In Czech]. A number of factors, such as surface treatments, e.g. sulphating, chromizing, and cold-working, have a small effect on the relaxation and creep properties of metals. These effects are reviewed, either on the basis of published data, or from results obtained by the author.—P. F.

The Spread of Creep Test Data. W. Stauffer and A. Keller. (*Schweiz. Arch. Wiss. Techn.*, 1957, **23,** Feb., 43–52). Creep and rupture tests show a considerable spread of values in any batch of material and from melt to melt. If, instead of evaluating the characteristics of each melt, a plot of values from a number of tests is made, a more reliable estimate of average and minimum values is obtained. Tests on various steels and particularly 18/8 stainless steels are illustrated and the good agreement with published American data shown.

Some Creep Tests on Steels for Prestressed Concrete. G. M. Canta. (*Metaalinst. Publ.*, 1956, June, No. 39, pp. 12). Samples of six steels were tested over a wide range of stress. Cold-drawn, cold drawn and aged, and hardened and tempered wires were used. Relaxation data are recommended.

Creep and High Temperature Alloys. R. W. Guard. (*Steel*, 1957, **140,** May 27, 108–118). The nature of the phenomenon of creep is described, and the effect of structure on the behaviour of metals is explained. A correlation is given by which some long-time creep results can be predicted from speeded-up tests.—D. L. C. P.

Combination Creep-Rupture Test Specimen. M. J. Manjoine. (*Amer. Soc. Test. Mat. Bull.*, 1957, May, 36–37). The dimensions of the test piece and typical results from it are shown.

The Laboratory Examination of Service Failures. F. R. Hutchings. (*Brit. Eng. Boiler Elec. Ins. Techn. Rep.*, 1957, **3,** 174–219). Procedure is described made up of 10 stages, not always all necessary, and illustrated with numerous examples. Appearances to be considered in visual and microscopical examination are carefully described and mechanical and chemical tests are noted. Consideration of the evidence and writing of reports are discussed. An appendix analyses relative incidence of common causes of failure. (38 references).

Fracture of a Connecting Rod Bolt. (*Brit. Eng. Boiler Elec. Ins. Techn. Rep.*, 1957, **3,** 128–130). Fatigue cracks developed at the junction of the head with the shank in a compressor. The bolt had been annealed after a period of service.

Hardness and Its Measurement. V. E. Lysaght. (*Metal Treating*, 1957, **8,** May-June, 2–4, 26, 27, 36–39, 42–45). Hardness is defined as the resistance to indentation. The significance of hardness testing and its correlation with tensile properties, machinability, wear resistance, fatigue life and microstructure are discussed. Brinell, Rockwell and Diamond Pyramid hardness testers are described. Reference is made to automatic and portable machines. The application of hardness testing to heat-treatment, case-hardening and decarburization detection is discussed. The merits of various methods of testing cast irons are outlined.

The Indentation Hardness of Diamond. P. Grodzinski. (*Schweiz. Arch. Wiss. Techn.*, 1957, **23,** Feb., 52–56). A review of tests made by the author and of published values that average indentation stress figures do not give an adequate measure of hardness. Whereas maximum stress figures obtained from Hartz formulæ give consistent hardness values. It is shown that the Hartz formula may be written in the form of a geometrical factor and a load factor for the various shapes of indentation point.—J. B. P.

Vickers-Microhardness and Elastic Recovery. H. Tertsch. (*Radex-Rundschau*, 1957, Feb., 495–497). Discussion of the regular distortion of Vickers hardness impressions leads to the conclusion that owing to the deformation of the angles of the "diagonal," explanations based on the plastic behaviour of the crystals are invalid. By a model experiment it is shown that the phenomena can be explained in terms of elastic recovery.

Nondestructive Determination and Control of Shallow Carburized Case Depths. R. Suffredini. (*Amer. Soc. Test. Mat. Bulletin*, 1957, July, 74–78). Correlation of Rockwell hardness with case depth was investigated.

Electronic Unit Tests Hardness of Gun Barrels. D. E. Briscoll and S. J. Acquaviva. (*Metalworking Prod.*, 1956, **100,** July 6, 1032–1033). An electrically operated controlled bore hardness tester has been developed by Watertown Arsenal and Robert C. Scott Inc. The instrument can accurately measure a 17 ft tube with bore diameters of 2½ in to 4 in.—M. A. K.

Towards the Greater Popularity of the Jominy Hardenability Test. M. Baj. (*Met. Ital.*, 1957, **49,** March, 186–194). [In Italian]. The author explains that the test has enjoyed only moderate popularity in Italy. The operating conditions and reproducibility of the test are discussed. The possibility of producing steels with controlled hardenability is reviewed. The technical and economic possibilities of the test are examined, particularly its helpfulness in assisting producers and consumers in selecting alloying elements and conditions of heat treatment. (48 references).—M. D. J. B.

Brittle Fracture Research in the United Kingdom. (*Admiralty Advisory Committee on Structural Steel, Report* No. P1, 1957, pp. 22). A review of present knowledge is followed by a list of bodies and companies working on the problem with notes on their research programmes. Actions are recommended on the testing of pedigreed materials and a committee is recommended to carry out tests as a matter of urgency.

Temper Embrittlement in Nodular Cast Irons. G. N. J. Gilbert. (*Amer. Found. Soc. Preprint*, 1957, No. 57–37, pp. 15). Previous work on galvanizing embrittlement in blackheart malleable iron and on temper brittleness in steels, is summarized and details are then given of an extensive series of results obtained on fully annealed ferritic nodular cast irons. The extent of temper embrittlement was established by determining fracture energy in testing temperature transition curves and by comparing room temperature impact values. Among the aspects investigated were Si and P content, tempering time and temperature, slow cooling from an embrittling temperature, Mo content, and the tensile properties of the embrittled irons. The author concludes that the embrittlement is similar in many respects to temper embrittlement in hardened and tempered steels, but that, unlike steels, both nodular and malleable cast irons are more embrittled when quenched from the embrittling temperature. In a nodular cast iron the embrittlement induced at 450° C is progressively but not necessarily completely removed during a slow cooling treatment.—B. C. W.

On the Causes of Irreversible Temper Brittleness in Steels. E. A. Stetsenko. (*Metallovedenie i Obrabotka Metallov*, 1952, **2,** (7), 35–38). Theories of the process are outlined. Specimens from two heats of 0·38–0·43% C, 0·8–1·1% Cr steel were heat-treated, ground to 10 × 10 mm and notched. Half were quenched from 820° in oil and tempered in a salt

bath, the others were twice quenched and similarly tempered. Impact value was increased in the latter but both showed a range of enhanced brittleness. It is concluded that retained austenite is not a factor in brittleness and that a precipitation theory (of carbides etc.) is more probable.

How to Distinguish Brittle from Tough Steel. H. Greenberg. (*Metal Progress*, 1957, **71**, June, 75–81). To insure freedom from brittle failure in service steel should have a nil-ductility transition temperature below its minimum working temperature. At temperatures below the nil-ductility temperature, samples with a sharp notch break with little prefracture deformation. Methods of measuring the transformation temperatures which have been used by the Westinghouse Electric Corporation are described.—B. G. B.

Abrupt Yielding and the Ductile-to-Brittle Transition in Body-Centered-Cubic Metals. E. T. Wessel. (*J. Met.*, 1957, **9**, July, Section 2, 930–935). Rimmed steels and Mo, Ta and Nb were examined, mechanisms are discussed and results reviewed. It is concluded that some non-elastic deformation is a necessary prerequisite and a process in terms of dislocation pile-up is outlined.

Brittle Fracture in Ductile Steel: Suggested New Method of Testing. S. A. Main. (*Iron Steel*, 1957, **30**, July, 365–367). The author points out the necessity for devising a test for brittle strength and, as a starting point, proposes a form of test in which the underlying principle is to use triple tensile stress as the means to effect brittle fracture. It is intended for static tensile operation, but could be adapted for impact testing.—G. F.

Some Instances of Cracking of Austenitic Stainless Steels. (*Brit. Eng. Boiler Elec. Ins. Techn. Rep.*, 1957, **3**, 67–75). Failure of a hydro-extractor basket, in all-welded rotating cylinders, and in a heating coil are quoted.

Design—Its Influence on Residual Stress and Brittle Fracture. J. L. Thomas. (*Welding J.*, 1957, **36**, Aug., 387s–392s). Studies on railway truck components are described.

The Influence of Temperature on Metallic Wear. J. K. Lancaster. (*Proc. Phys. Soc.*, 1957, **70**, Jan. 1, 112–118). Brass on tool-steel was examined. Wear decreases at high temperatures and protective films form. The main effect of temp. appears to arise from the effect of the atmosphere on the sliding metals.

Wear Resistance Examination of Inoculated Grey Iron in the Laboratory and Railway Practice. F. Varga and E. Füle. (*Kohászati Lapok*, 1955, **10**, April, 85–91). Hungarian laboratory and full-scale examinations have shown that the wear resistance of railway brake shoes made of nodular grey iron, inoculated with CaSi, is higher than that of normal grey iron or nodular grey iron, inoculated with FeSi, for the same hardness.—P. K.

Studies on Mechanical and Wear-resisting Properties of Low Mn-Mo Steel Castings. S. Miyazaki. (*Tetsu to Hagane*, 1957, **43**, Mar., 466–470). [In Japanese]. The castings had compositions: (*a*) 0·36% C, 1·63% Mn, 0·32% Mo, and (*b*) 0·41% C, 1·20% Mn, 0·22% Mo. Castings in (*a*) had better mechanical properties than (*b*), and homogenizing and double normalizing treatments were effective for toughening; they had higher hardness as annealed, and machining was more difficult. Those in (*b*) had better wear-resistance.

A Device for Testing the Wear Resistance of Surface Coatings. J. McCarthy and J. Morgia. (*Plating*, 1956, **43**, Oct., 1248–1250). A machine used for testing the wear resistance of anodic and paint coatings is described. The samples are rotated at high speed through a falling stream of abrasive powder and loss-in-weight or time taken to break through the coating is taken as a measure of wear resistance.

On the Origin of Peaks of Internal Friction Connected With the Diffusion of Carbon, Caused by Stresses in Alloy Steels with a Face-centred Cubic Lattice. Ke Tun-Sui and Tzen Chu-tszyan. (*Fizika Metallov i Metallovedenie*, 1957, **4**, (2), 291–305). [In Russian]. Three of the alloy steels investigated contained varying proportion of Mn, and the fourth contained, besides Mn, Ni and Cu. The greatest internal friction was observed at 250° at an oscillation frequency of 2 cycles per sec. The experimental results show that the height of the peaks depends linearly on the concentration of C in the solid solution.—L. H.

Advantages and Limits of Nondestructive Testing. H. Krainer. (*Nondestructive Test.*, 1957, **15**, July-Aug., 234–240). A general review of factors in the choice of methods, including economic factors, is given. Various examples of testing steel specimens are described.

A Critical Survey of the General Limitations of the Non-destructive Testing Field. D. W. Ballard. (*Nondestructive Test.*, 1957, **15**, July-Aug., 198–207). Five main headings are used: Limitations of trained man-power, limitations in foresight, limitations of technology, and limitations of methods and equipment, recommendations are added under each topic. (26 references and bibliography).

The Basis for Optimum-Test-Methods Selection. J. Thewlis. (*Nondestructive Test.*, 1957, **15**, July-Aug., 210–216). Non-destructive methods are classified and a system of data cards is explained intended to facilitate choice of appropriate technique. The need for a glossary in the field is noted and medical testing is indicated as a branch of non-destructive study.

Magnetic and Electromagnetic Methods of Non-Destructive Testing of Materials. A. Constantinescu and M. Savulescu. (*Met. Constr. Masini*, 1956, **8**, (9), 3–12). [In Rumanian]. This is a review of the purely magnetic and electromagnetic methods of non-destructive testing for metals, giving the principles involved and the theory of these tests.—L. H.

Magnetic Testing of the Quality of Hardening and Tempering of Ball- and Roller-Bearing Parts. M. N. Mikheev, G. S. Tomilov, M. F. Pomukhin, K. G. Rzyankin and V. A. Utkina. (*Zavodskaya Laboratoriya*, 1956, **22**, (5), 549–555). [In Russian]. Some relationships between the magnetic properties of steel and its previous heat treatments are discussed, and a technique, based on these relations, is described by which the correctness of hardening and tempering of large bearing rings can be checked. For this a special differential magnetic device has been developed and extensively tested. Magnetization is effected in strong fields with induction values close to saturation, the duration of a test being 15–30 sec. Results obtained magnetically are presented and compared with microstructure and hardness determinations. The technique is recommended for large-scale testing of parts varying widely in shape and size.—S. K.

Measurement of the Magnetic Characteristics of Electro-Technical Steel According to the New Standard. V. V. Druzhinin. (*Zavodskaya Laboratoriya*, 1956, **22**, (8), 949–953). [In Russian]. The Soviet standard specifications for electrical-engineering steels have recently been revised and extended in the present article. An important new departure is that magnetic induction in weak and medium fields is included.—S. K.

On the Magnetic Ageing of Commercially Pure Iron. M. Asanuma and S. Ogawa. (*J. Phys. Soc. Japan*, 1957, **12**, Aug., 955–958). A remarkable decrease occurs on tempering near 130° C. This is due to small amounts of C and N and the effect of nitride is greater than that of carbide. Mechanisms are suggested in terms of saturation magnetization and solubility limits in α-iron.

Determination of the Relation Between The Magnetic Crystal Structures of Silicon-Iron and Their Thickness. V. P. Abel's and Ya. S. Shur. (*Fizika Metallov i Metallovedenie*, 1956, **3**, (3), 433–438). Changes in the closed surface domains depend on the thickness of the crystals. One may surmise that the crystals of silicon iron possess many anisotropic constants, the greater the angle of magnetization (with the surface of the specimen [direction (100)] the deeper the extent of the closed domains). It follows that a change in the magnetic structure with diminishing thickness of the specimen determines the anisotropic forms. This anisotropy is responsible for the reformation of the magnetic structure in many sections of the specimen, so that the magnetization vectors spread along the direction (100) i.e. along the axes of easy magnetization.—L. H.

Magnetic Anisotropy in Connexion with Rolling in the Course of Producing Single Crystals of Silicon Steel. T. Yamashita and E. T. Tatsumoto. (*J. Phys. Soc. Japan*, 1957, **12**, Aug., 975). The effect is attributed to pinholes lined up parallel to the direction of rolling.

The Wiedemann Effect of the Magnetostriction Alloy "Alfer." Y. Shirakawa, T. Ohara and T. Abe. (*Sci. Rep. Res. Inst. Tohoku Univ.*, 1957, **9**, June, 176–183). **At High Temperatures.** (184–189). Measurements at room temperature and at temperatures up to ~ 800° are reported. The angle of twist increased with increasing longitudinal field and passed through a maximum at constant current. The effect of "Alfer" is opposite in sign to Ni though of nearly

equal magnitude. The effect decreases with rise of temperature, becomes extremely small at the magnetic transformation temperature of the Fe_3Al superlattice and disappears at that of the α-phase. Ni is similar but Fe behaves differently.

The Dependence of the Magnetic Induction of Hot Rolled Transformer Steels in Strong Fields on Sheet Thickness. B. F. Trakhtenberg. (*Fizika Metallov i Metallovedenie*, 1956, **3**, (2), 222–228). [In Russian]. The relation between the magnetic induction of hot-rolled transformer steels in strong fields and sheet thickness has been investigated. With a reduction in thickness the magnetic induction diminishes slightly. An explanation is offered of a relation between the size of the grains and the lowering of the magnetic induction in strong fields, and the demagnetizing influence of the sheet surfaces.—L. H.

Investigation of Domain Structure Dynamics in Transformer Steel Crystals by the Use of Cinematography. L. V. Kirenskii and V. D. Dylgerov. (*Fizika Metallov i Metallovedenie*, 1956, **3**, (2), 216–221). [In Russian]. The powder pattern method of investigating the dynamics of crystal structure cannot give a complete picture since it reveals only fixed structures. By applying for the first time cinematography to the powder pattern formations, it is possible to observe directly the dynamics of crystal structure during changes in the magnetic field strength. The method can also be used for investigating the dynamics of crystal structure in relation to other factors such as variations in tension, in temperature etc.—L. H.

The Effect of the Ordering Process on the Temperature Dependence of the Magnetic Properties of a Fe–Ni–Mo Alloy. M. V. Dekhtyar. (*Fizika Metallov i Metallovedenie*, 1956, **3**, (1), 55–61). [In Russian]. The anomalous dependence of coercive force and of magnetic saturation on temperature is an indication of the process of formation of bainite in the crystalline lattice of the single phase alloy.—L. H.

On the Constants of Magnetic Anisotropy of Silicon Steel Alloys. V. V. Druzhinin. (*Fizika Metallov i Metallovedenie*, 1956, **3**, (1), 47–54). [In Russian]. In the calculation of the constants of magnetic anisotropy account was taken of 3 terms in the expression for the free energy of magnetic anisotropy. The alloys contained from 3·0 to 3·7% Si, and their crystallographic orientation was such that the type (110) face was parallel to the discs. The constant of magnetic anisotropy was determined by the mechanical moment acting on a fixed monocrystal disc in a strong magnetic field.—L. H.

Magnetic Properties of Chromium Steel Sh Kh 15 After Various Heat Treatments. M. N. Mikheev, I. A. Kuznetsov, V. A. Kryukova and B. M. Neizvestnov. (*Fizika Metallov i Metallovedenie*, 1956, **3**, (2), 229–237). [In Russian]. The investigation was conducted with a view to discovering the possibility of qualitative magnetic control for the various heat treatments and to selecting the optimum magnetic characteristics to this end. The unexpected fact was established that the alteration in the magnetic properties during long periods of overheating (to 1100–1150°) did not materially differ from those during quenching from 830–850°). An explanation is suggested that the constituents in the steels may influence these magnetic properties, but in view of this it is recommended to extend magnetic control over two characteristics, over magnetization to saturation or magnetic permeability to maximum, and over the coercive force. This is the only means of revealing flaws by the magnetic control device.—L. H.

The Nernst Thermomagnetic Effect in Iron–Nickel Alloys. E. P. Svirina and R. P. Ivanova. (*Fizika Metallov i Metallovedenie*, 1956, **3**, (3), 444–448). [In Russian]. By analogy with the electromotive force, it is permissible to deduce the Nernst EMF from the formula $E = Q_1 b(T_1 - T_2)/l \times I$, where Q_1 is the Nernst constant, b the thickness of specimen, l the length of specimen, along which is produced the constant temperature gradient and I the magnetization. This investigation covered the Nernst effect in iron–nickel alloys, the relation of Nernst constant and emf to the composition of the alloys, to the internal magnetic field, to variations in temperature, etc. The results are tabulated.—L. H.

Alteration in the S. S. Steinberg's Magnetometer, for Obtaining Martensite Graphs. B. P. Gusynin. (*Zavodskaya Laboratorya*, 1956, **22**, (11), 1370–1371). [In Russian]. In general laboratory practice the magnetometer of the S. S. Steinberg type is used to establish the diffusion of quenched austenite at temperatures not lower than room temperatures. Small alterations carried out by the authors enabled them to extend the temperature limits of the apparatus to — 180° C.—L. H.

The Abrasion Resistance at High Temperatures of Iron-Chromium-Nickel. G. Faber. (*Schweiz. Arch. Wiss. Techn.*, 1957, **23**, Jan., 14–19). The Fe-Cr sigma-phase is resistant to high-temperature abrasion but is very brittle. If this alloy is finely dispersed in a matrix of sufficient strength the abrasion resistance can be obtained by the diffusion of Cr to form a skin. Investigations are described using 30–37% Cr, 13% Ni, balance Fe, and cooling rapidly after solidification to precipitate the sigma-phase.—J. R. P.

The Effect of Surface Abrasion on the Hydrogen Content of Steel. F. Cooke and C. E. A. Shanahan. (*J. Appl. Chem.*, 1957, **7**, July, 388–392). Abrasion on SiC paper increased H_2 content by 0·0049 in a mild steel and by 0·0034 in a stainless steel in ml/cm² of abraded area. The effect on the determination of H_2 in steel is discussed.

Materials for Wear Resistance. V. Pulsifer. (*Machine Design*, 1956, **28**, May 31, 126–129). A broad-scale summary of recent materials, coatings and processes developed for low friction and wear resistance.—M. A. K.

Contributions to the Evaluation of Photoelastic Experiments on Discs and Plates. A. Kuske. (*Forsch. Ingenieurwesens*, 1957, **23**, (1/2), (16-21). Relations are derived for the determination by equation or nomogram of the direction of lines of constant stress on discs or plates undergoing transverse bending.—J. R. P.

Magnetic Susceptibility of Iron–Nickel Alloys in Liquid and Solid States. Y. Nakagawa. (*J. Phys. Soc. Japan*, 1957, **12**, June, 700–707). It is suggested that the atomic magnetic moments remain unchanged and that interaction varies with interatomic distance.

High-Frequency Magnetic Measurements. (*Nat. Bur. Standards Tech. Bull.*, 1957, **41**, June, 91–92). A permeameter of increased accuracy is described.

On the Complex Permeability of Iron-Nickel Alloys at High Frequencies. J. C. Anderson and B. Donovan. (*Proc. Phys. Soc.*, 1957, **70**, Feb. 1, 186–191).

On Ferrosilicon with Cube Texture. I. Magnetic Investigations. F. Assmus, R. Boll, D. Ganz and F. Pfeifer. (*Z. Metallkunde*, 1957, **48**, June, 341–343). **II. Formation of the Texture.** F. Assmus, K. Detert and G. Ibe. (344–349). Induction and torque occur in different directions in the magnetization of 3% Si iron with cubic texture. Preferential directions are in the plane of rolling parallel and perpendicular to the direction of rolling and the magnetic properties are similar. Comparison with Goss material which has one preferential direction only is made. Kinetics of secondary recrystallisation show how the texture is formed. During annealing growth of cube-oriented grains is stimulated and the remaining matrix is consumed.

On the Occurrence of Sounds During the Melting and Solidification of Metals. J. Kaiser. (*Forsch. Ingenieurwesens*, 1957, **23**, (1/2), 38–42). An electro-acoustical apparatus is described in which the intensities and frequencies of noises occurring in metals during melting or solidifying are detected and recorded. Various base metals and base metal alloys were investigated and frequency spectra are illustrated. It is considered that the method is complementary to conventional methods for investigating changes of state or internal structure and may lead to additional information being obtained.— J. R. P.

Ultrasonic Examination of Metallurgical Products. P. Réti. (*Kohászati Lapok*, 1955, **10**, May, 215–222). Reference is made to the detection of internal flaws with a Kroutkrämer instrument of the impulse system in blooms, billets, bars, big forged components, plates 4-60 mm and tubes of wall thickness 32 mm. Flaws of size more than 1 mm² at a depth of 50–500 mm and more than a few mm² at 850 mm depth may be detected with this instrument used on a sufficiently smooth metallic surface.—P. K.

Ultrasonic Testing of Sheet Metal. H.-J. Kopineck and H. Hoff. (*Stahl u. Eisen*, 1957, **77**, May 30, 727–734). Lamination and non-metallic inclusions are the main defects occurring in sheet metal. The authors describe the layout of an ultrasonic testing device for the detection of lamination and non-metallic inclusions. They stress that testing of blooms and slabs is important. Impulse-reflection and transmission methods are used according to the thickness of the material. The transmission method is also used for testing sheet in the longitudinal direction. The design of probe heads and

devices for applying the contact liquid continuously are also described as well as mode of operation, accuracy obtained, etc.—T. G.

Standardisation and Application of Ultrasonic Surface-Wave Inspection. G. J. Binczewski. (*Non-Destructive Test*, 1957, **15**, Jan.-Feb., 36–40). Surface conditions that influence the propagation of surface waves and the response of waves as affected by distance, depth, and the edge angles of surface imperfections are reported. Correlation of test data with the nature and effects of surface imperfections indicates that reliable standards can be developed. Applications of surface-wave inspection are discussed and illustrated.

Versatile Ultrasonics Widens Its Metalworking Range. G. G. Carr. (*Iron Age*, 1957, **179**, June 13, 83–85). Present and prospective applications of ultrasonics are described. Reference is made to its use in plating, heat treatment, quenching and etch-milling.—D. L. C. P.

Sound "Sees" Rejects Before They Happen. (*Steel*, 1957, **141**, July 1, 66–69). Reports from eight firms representing manufacturers and users of ultrasonic test instruments indicate the value of ultrasonic inspection. Tests on castings, welded parts and heavy plates are described.

An Ultrasonic Scanner and Recording System. W. N. Beck. (*Non-Destructive Test*, 1957, **15**, Jan.-Feb., 42–43, 46). An ultrasonic scanner which is suitable for research and able to handle production volume is described. Several tests which were carried out to examine the detection and resolution of defects in various materials are discussed.

Relationship Between Defect Orientation and Ultrasonic Indications. R. E. Kleint. (*Non-Destructive Test*, 1957, **15**, Jan.-Feb., 30–34). Results of research relating defect orientation to ultrasonic indications are presented. The defects examined ultrasonically were oriented at angles from 0–45° to the surface. Attenuation of ultrasonic indications as a result of oblique defect orientation is shown for various crystal frequencies from 2¼ to 25 megacycles. Experimental results are compared with theoretical estimates for the relationship between defect orientation and crystal orientation for maximum indications. These exist when geometrical conditions of Snell's Law are fulfilled.—A. H. M.

Ultrasonic Testing of Large Forgings. V. Koblovský. (*Hutnické Listy*, 1957, **12**, (4), 302–309). [In Czech]. Three large rotor forgings, rejected by the works as faulty after manufacture, were examined by ultrasonics. The nature of the flaws thus indicated was checked by sectioning the forgings. This method of checking can provide a valuable basis for the diagnosis of faults in forgings.—F. F.

Note on the Problem of the Classification of Defects by Ultrasonic Examination. H.-J. Seemann and W. Bentz. (*Rev. Mét.*, 1957, **54**, July, 529–536). Oscillograms are shown and correlated with microstructure in cracked and otherwise defective specimens.

Field Performance of a Television X-Ray System. H. Berger and A. L. Pace. (*Non-Destructive Test.*, 1957, **15**, Jan.-Feb., 26–29). A television X-ray system employing a large-area photoconductive X-ray pickup tube is described. Contrast sensitivities of the order of 2–6% are observed over the range from 40 to 300 kvp, increasing to 10% at 2 Mev and to 20% at 6 Mev. Resolution is of the order of 0·01 in. Viewing of the X-ray image can be carried out in a normally illuminated room. Some typical applications are discussed.

A Gammascopic Apparatus for the Detection of Cavities in Hot-Rolled Semi Products at the Temperature of Rolling. A. Kohn. (*Rev. Mét.*, 1957, **54**, April 299–319). The equipment described includes a source of radio-cobalt and a scintillation counter. The presence of a cavity causes an increase of the activity measured by an integrator and is registered as a peak on the recording apparatus. Danger from radiation is avoided by automatic screening of the source. The theoretical principles involved are explained. The results are described of tests carried out in a works on blooms of 200 mm thickness passing at speeds of 1 to 15 m/min.—B. G. B.

Effect of Neutron Irradiation on the Mechanical Properties of Some Structural Steels. E. E. Baldwin. (*Welding J.*, 1957, **36**, July, 342s–347s). ASTM A302B and A201 steels were irradiated at 500–700° F and 300–400° F respectively. Little or no change was produced in the former but the latter increases in strength and loses ductility. This is substantially recovered by annealing at 600° F.

Directional Dilatation of Crystal Lattices at Elevated Temperatures. R. J. Beals and R. L. Cook. (*J. Amer. Ceram. Soc.*, 1957, **40**, Aug. 1, 279–284). An X-ray back-reflection method is described and values are given for MgO, Al_2O_3 and other crystals including spinels.

Material Testing At Low Temperatures. H. Hildesheimer. (*Schweissen u. Schneiden*, 1957, **9**, Mar., 117–119). Brittleness at low temperatures is investigated. Cooling devices are described in which the test example is cooled to a very low temperature, the cooling media being liquid hydrogen and liquid helium.—U. E.

Properties of Cast Iron at Elevated Temperatures: A Progress Report. J. R. Kattus. (*Iron Steel.* 1957, **30**, July, 356; *Amer. Soc. Test. Mat. Bull.*, 1957, May, 12). Following a literature survey of the properties of cast iron at elevated temperatures, screening tests on 12 commercial cast-iron alloys were carried out and the seven most promising were chosen for further investigation. This progress report outlines the results of creep-rupture tests at 800° and 1000° F for times up to 5000 hours, and of thermal shock tests, on the seven irons.

Mechanical Behaviour of Steels at High Temperature. A. Galbiati. (*Acciaio Inossid.*, 1957, **24**, Jan.-Feb., 3–14). [In Italian]. This paper discusses the application of stress to steels and the resulting deformation. The effects of temperature are studied in detail. Plastic limits and ultimate strengths are also discussed and a method is put forward for calculating their values which gives good agreement with the observed results.—M. D. J. B.

On Some Magnetic Properties of Dispersion-Hardened Alloys Fe–Mo and Cu–Ni–Fe. V. I. Ivanovskii. (*Fizika Metallov i Metallovedenie*, 1957, **4**, (2), 245–248). [In Russian]. Investigation of the Fe-Mo alloys with 18% Mo by weight was carried out on specimens hardened at 1300° in high-frequency furnaces and then water quenched, and covered the kinetics of the change of coercive force (within the temperature of break-up of the solid solution) the magnetic susceptibility and viscosity. The same investigation was carried out also on the alloy Cu–Ni–Fe on specimens annealed at 650° after preliminary hardening at suitable temperatures during varying periods. The results are tabulated and graphically represented.—L. H.

Investigation of the Coercive Force of Cold Deformed and Annealed Iron Alloys. G. M. Fedash. (*Fizika Metallov i Metallovedenie*, 1957, **4**, (2), 257–266). Changes in the coercive forces of the systems in cold plastic deformation, and during annealing, prove analogous in character to the changes of the coercive forces of the alloyed components both above and below the critical A_3 point. This experimental study extends to the different diffusion processes during the spreading of the components in deformation and in incomplete annealing of Fe–Mn and Fe–Ni alloys.—L. H.

On the Change of Temperature in the Spontaneous Magnetization of Alloys Near the Curie Points. K. Belov and Ya. Paches. (*Fizika Metallov i Metallovedenie*, 1957, **4**, (1), 48–53). [In Russian]. The results of this experimental study have been obtained by three methods of investigation, by the galvano-magnetic effect, by the lines of equal magnetization and by the thermodynamic coefficient, and they refer to electrolytic nickel, to a Ni–Si alloy, to two Ni–Mn alloys and to one alloy of invar type, 38% Ni and 62% Fe. A difference in the results obtained by these methods was found, and it was noticed that this difference increased with the increase in the concentration of the various components of the nickel alloy. The theoretical implications of the investigation are discussed and some explanations advanced.—L. H.

On the Magnetic Properties of the Alloy Fe_3Al. V. I. Ivanovskii. (*Fizika Metallov i Metallovedenie*, 1957, **4**, (1), 70–75). [In Russian]. The investigations covered the surface-conversion in these alloys. The specimens were in the form of cylinders of 4 mm diam. and 47 mm length. The measurements were made with an astatic magnetometer with a sensitivity of 10^{-2} gs/mm for the determination of the relation between the temperature, the force coefficient and the initial susceptibility of the alloy. Further investigations extended to the growth coefficient of the regulating force, and to the susceptibility near the Kurnakov temperatures, and to the kinetics of the viscosity in the regulating process.

Self-Compensating Coercive-Force Meter Based on a Magnetic Amplifier. L. A. Fridman and V. P. Ankudinova. (*Zavodskaya Laboratoriya*, 1956, **22**, (9), 1108–1110). [In Russian]. The use of a magnetic amplifier in a scheme for the large scale automatic coercive-force measurement of

electrotechnical iron is described, a circuit diagram and performance curves being shown.—S. K.

Thermal and Thermoelectric Properties of Silicon Alloys with Transition Metals. P. V. Gel'd. (*Zhur. Tekn. Fiz.*, 1957, **27**, (1), 113–118). [In Russian]. Heat and temperature conductivities of iron silicon alloys (1–99% Si) were measured. The dependence of the above conductivities on temperature was expressed by empirical equations. The relationship between the coefficients of heat conductivity and thermal expansion was investigated. Thermo e.m.f. of alloys of Si with Fe, Cr and Mn was studied.—V. G.

The Velocity of Sound as a Characteristic Value for the Quality of Cast Iron. R. Ziegler and R. Gerstner. (*24th International Foundry Congress Papers*, 1957, 133–157). Ultrasonic radiation is used and the approximate relationship to modulus of elasticity related to amount of graphite, degree of saturation, tensile stress, disintegration of texture and amount of spherolites in spheroidal iron.

Ultrasonic Testing With Lamb Waves. D. C. Worlton. (*Nondestructive Test.*, 1957, **15**, July-Aug., 218–222). Vibrational waves travelling in an elastic plate can be used, not only for thin sections, for flaw detection. The technique eliminates surface echo.

Method of Finding Deep-Seated Defects in Metals with the Aid of Transverse Ultrasonic Vibrations. O. O. Kuz'mina, N. G. Minaev and A. P. Pshenichnikov. (*Zavodskaya Laboratoriya*, 1956, **22**, (8), 943–949). [In Russian]. A method suitable for detecting deep-seated defects in cylindrical parts with the aid of transverse ultrasonic vibrations has been developed. For hollow cylindrical parts with wall-thickness up to 100 mm the most effective technique was found to be double sounding from the side surface with a curved prismatic probe with the piezo-element inclined at an angle of 30°. A quantitative relationship has been established between the various types of defect and the amplification of the instrument; defects in centrifugally cast steel cylindrical parts have been classified.—S. K.

Ultrasonic Impulse-Reflection Method for Testing Turbine Discs. B. Ya. Litvinenko. (*Zavodskaya Laboratoriya*, 1956, **22**, (9), 1068–1070). [In Russian]. The application of different ultrasonic techniques to flaw detection in turbine discs is described and some results are compared with those obtained magnetically.—S. K.

Testing Sheet Metal for Lamination by an Ultrasonic Method. P. P. Khramov and G. V. Prorokov. (*Zavodskaya Laboratoriya*, 1956, **22**, (9), 1065–1068). [In Russian]. An ultrasonic lamination detector is described for which high reliability is claimed. The device has been used successfully with 3·5 mm thick steel sheet moving at 1m/min.—S. K.

Probability of Detection of Defects of Hollow Forgings by the Ultrasonic Method. T. Otsuka. (*Tetsu to Hagane*, 1957, **43**, Mar., 307–309). [In Japanese].—K. E. J.

Investigation of the Powder Patterns of Crystals of Transformer Steels. V. D. Dylgerov. (*Fizika Metallov i Metallovedenie*, 1956, **3**, (1), 42–46). [In Russian]. Each steel crystal not previously subjected to any preliminary treatment except that of electropolishing, possesses only two types of powder pattern of which one shows the magnetic structure of the Lifshits model with surface domains of the closed types and the other shows the flat parallel domains of its surface without formation of closed types. Under the influence of weak stresses, a transformation from one pattern to another takes place in the crystals along the axes of easy magnetization. This is easily explained by the model of magnetic structure proposed by Landay and Lifshits.—L. H.

Crystallography of Cold Drawn Music Wire. H. C. Burnett and C. J. Newton. (*Nat. Bur. Standards Techn. News Bull.*, 1957, **41**, Aug., 118–119). An investigation of preferred orientation has been completed showing line broadening from the (110) plane at various stages of reduction and relating Young's modulus to reduction in diameter %.

The Use of Gamma-Radiation for the Control of Thin Components. N. V. Ushakov. (*Zavodskaya Laboratoriya*, 1956, **22**, (12), 1452–1455). [In Russian]. A procedure is explained for using many present day gamma-radiating isotopes for the control of thin components, in cases where this method can advantageously replace the X-ray process. Experiments are described with the use of ^{181}W, ^{75}Se, ^{192}Ir ^{110}Ag and ^{60}Co, where in some cases gamma-radiation gives clearer pictures than the conventional X-ray method.—L. H.

Isotherms of Heat Conductivity of Silicon and its Alloys with Iron at Elevated Temperatures. B. B. Kuprovskii and P. V. Gel'd. (*Fizika Metallov i Metallovedenie*, 1956, **3**, (1), 182–183). [In Russian]. The alloy specimens contained from 1 to 98·8% Si and were submitted to temperatures ranging from 100 to 950°. The calculations were recorded durin; radial heat flow in thick-walled cylinders.—L. H.

The Determination of the True Physical Properties from the Mean Value, Particularly in the Case of the Thermal Conductivity. W. Bolte. (*BWK*, 1957, **9**, Aug., 373–375). The thermal conductivity, specific heat and other physical constants of many materials are often tabulated in terms of mean values, each applicable to a given temperature range. By a simple technique, presented in the paper, it is possible to estimate the actual value of the parameter at any given temperature from such a set of means.—P. F.

Effect of High Pressure on the Heat Properties of Solids. K. P. Rodionov. (*Fizika Metallov i Metallovedenie*, 1956, **3**, (1), 26–30). [In Russian]. The aim of this work was to submit to experimental verification the quantitative dependence of the thermal coefficient of expansion and the thermal capacity of a solid on the pressure. The outcome of the experiment tends to show that under high pressure of physical changes in the internal energy of a solid do not derive so much from the rise in temperature, as from the consequent increase in the elastic forces.—L. H.

Mode of Determining the Fusion Temperature of Refractory Metals and Alloys. V. P. Elyutin and V. F. Funke. (*Zavodskaya Laboratoriya*, 1956, **22**, (12), 1444–1448). [In Russian]. A method is proposed for determining the fusion temperature of metals and alloys by the fusion of flat specimens by means of an electric current. The fusion temperature of the specimens can be taken, without essential error, to represent the fusion temperature of the respective alloys.—L. H.

Automation of Machines for Hot Strength Testing. A. V. Antonovich. (*Zavodskaya Laboratoriya*, 1956, **22**, (9), 1100–1105). [In Russian]. The author discusses the automation of prolonged high-temperature mechanical tests, the aspects considered including an electronic temperature regulator, time recorder, temperature registration and centralized control.—S. K.

Comparison of Results of Testing Metal for Fine Cracks in Billets and in Finished Products. Z. M. Kalinina. (*Stal'*, 1957, (3), 261–263). [In Russian]. Comparison of consumers' test results, obtained by magnetic flaw detection on their products, with those obtained by the steelmakers on graded-diameter test-pieces from the billet shows the uselessness of the latter test.—S. K.

The Determination of Magnetic Reversal Losses in Electric Sheet by Means of Non-destructive Tests. G. Wollweber. (*Arch. Eisenhüttenwesen*, 1957, **28**, July, 397–399). Results of measurements to date with the apparatus developed by W. Krug are reported. Induction is automatically controlled with an accuracy of $\pm$ 0·5%; magnetic reversal losses are reproducible within $\pm$ 1%.—L. J. L.

Thermo-Magnetic Properties: Magnetic Saturation in the Study of Solid State Transformations and of Powder Metallurgy. M. P. de Andres Sanz. (*Inst. Hierro Acero*, 1957, **10**, Jan.-Mar., 80–96). [In Spanish]. The details of the construction, calibration and operation of a Mathieu type magnetic balance are given. This is followed by data on the above topics obtained by the author and by others using similar apparatus. (12 references).—P. S.

The Use of Eddy-Currents for Control in Metallurgical Production. A. Valášek. (*Hutník*, 1957, **7**, (5), 161–164). [In Czech]. A number of applications of sorting bridges and other instruments utilizing eddy currents are described, with special reference to uses with non-ferrous metals.—P. F.

The Use of Ultrasonics in Non-Destructive Testing of Materials. L. Scuri. (*Calore*, 1957, **28**, May, 197–202). [In Italian]. The general principles of ultrasonic techniques are described and the practical uses reviewed. Penetration, resonance and echo methods are described. The use of ultrasonics in testing the soundness of welds is considered.

Immersed Ultrasonic Inspection of Pipe and Tubing. R. B. Oliver, R. W. McClung and J. K. White. (*Non-Destructive Test.*, 1957, **15**, May-June, 140–144). Continuous inspection at high rates of travel of tubes from $\frac{1}{2}$–8 in. dia. can be carried out with the apparatus described.

Testing for Damping Capacity of Cast Iron with Ultrasonics. G. Keller. (*Kohászati Lapok*, 1956, **11**, *Öntöde*, April, 73–84).

The damping capacity, measured by ultrasonics is greatly influenced by the quantity, size, shape and distribution of graphite particles enclosed in the matrix. A new numerical determination of damping capacity is given. Ultrasonic testing for damping capacity may be carried out satisfactorily and quickly, even on small specimens, without any difficulties.

Ultrasonic Inspection in the Oil-Refining and Related Industries. D. J. Evans. (*Non-Destructive Test.*, 1957, **15**, May-June, 156–160). Measurement of steel plate thickness from one side, as in tanks and pipelines, and flaw and crack detection in shafts and in seam testing are reviewed.

Ultrasonic Transmission Tester. J. D. Ross and R. W. Leep. (*Non-Destructive Test.*, 1957, **15**, May-June, 152–154). A device for transmitting and counting pulses for abnormal attenuation is described and its use for examining the bonding of Al to U fuel elements explained.

Supervision of Production by Means of Non-destructive Tests. H. Kostzewske. (*Metall*, 1957, **11**, July, 582–586). The methods here surveyed comprise televised radiography, thickness measurement by X- and γ-rays and by pneumatic means, with digital indication, X- and γ-ray level indication, ultrasonic eddy current and inductive methods.—J. G. W.

Some Practical Aspects of X-Ray Examination of Steel Castings. R. Kottra. (*Kohászati Lapok*, 1955, **10**, *Ontöde*, Sept., 197–205). A short review is given of the X-ray and γ-ray examination of steel castings of 70–600 mm wall thickness, using an electron gun for the former and radioactive isotopes for the latter purposes. Afterwards a comprehensive review is given of a Hungarian method of X-ray examination of steel castings, using normal 250Kv equipment. This method is applicable to the determination of sand inclusions, blowholes, gas bubbles, cracks and shrinkage cavities. Examples are given.—P. K.

The Use of Multiple-Film Techniques to Speed Industrial Radiographic Inspection. R. E. Turner. (*Non-Destructive Test.*, 1957, **15**, May-June, 146–150). The use of 2 or 3 films of different speeds to record detail in parts of different thicknesses is described.

Approximate Method for the Calculation of Exposure Values in Gamma-Radiography Using Iridium 192 and Caesium 137. W. H. Papke. (*Schweissen u. Schneiden*, 1957, **9**, July, 349–353). The author discusses the various factors that determine the exposure values in gamma-radiography with ^{192}Ir and ^{137}Cs. He presents a nomogram for the radiography of steel. The nomogram consists of two parts; one of them has to be cut out and slid over the other.—T. G.

On the Theory of Gauge Measurement by Absorption Radiography. W. Dahl. (*Stahl u. Eisen*, 1957, **77**, June 27, 884–886). This is a review of work published by A. M. Bogatschew, B. J. Werchowsky, and A. N. Makarow in *Sawodskaja Laboratorija*, 1955, **21**, 808, on the relation of error in gauge measurement and the inherent inaccuracy in the determination of the intensity of the radioisotopes. Equations and diagrams for the correct determination of the gauge are derived.—T. G.

Industrial Uses of Radio-Isotopes. E. N. Shaw. (*Overseas Eng.*, 1957, **31**, Sept., 60–62). A review of applications including thickness gauging and furnace level indicators.

The Use of Artificially Radioactive Isotopes in the Study of the Processes of the Production of Steel and Iron. A. M Samarin. (*International Conference on the Peaceful Uses of Atomic Energy*, 1955, A/Conf. 8/P/707. U.S.S.R. July 5, pp. 28). [Translated from Russian]. Determinations of thermodynamical functions, dephosphorization and desulphurization, slag formation, rate of scrap melting, non-metallic inclusions, crystallization processes, blast furnace operation, ore beneficiation and observation of furnace wear are outlined. (33 references).

Neutron Radiation. M. L. Bleiberg. (*Mech. Eng.*, 1957, **79**, Aug., 781–782). A comment on the paper by E. E. Baldwin, (*ibid.*, Mar., 261–265). Neutron bombardment of pressure vessel steel is reported and discussed.

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Method of Constructing Diagrams of True Stresses at Elevated Temperatures. V. V. Morekina. (*Zavodskaya Laboratoria*, 1956, **22**, (12), 1491–1492). [In Russian]. A procedure is described for obtaining by graphical methods, diagrams of true tensile stresses at elevated temperatures; a method which is suitable for light, semi-light, heat-resisting and highly ductile alloys.—L. H.

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Influence of Addition of Copper on the Characteristics of an Elinvar Type Alloy "Co-Elinvar." I. Alloys Containing 5% Copper. H. Masumoto, H. Saito and Y. Sugai. (*Sci. Rep. Res. Inst. Tohoku Univ.*, 1957, **9**, June, 171–175). Thermal expansion, rigidity modulus and its temperature coefficient are studied. Copper has little effect, but it narrows the range of minimum thermal expansion. Some alloys high in chromium have a rigidity modulus above 8×10^5 kg/cm².

On the Activities of Manganese and Carbon in Molten Fe–Mn–C Alloys. M. Ohtani. (*Tetsu to Hagane*, 1957, **43**, Mar., 294–295). [In Japanese]. Data are given relating to the activity of Mn in molten Fe–Mn–C alloys at about 1530° C, for several carbon contents between zero and saturation.

The Influence of Manganese on the Activity and Solubility of Oxygen in Liquid Iron. V. V. Averin, R. A. Karasev, A. Yu. Polyakov and A. M. Samarin. (*Izvest. Akad. Nauk, S.S.S.R., Otdelenie Tekh. Nauk*, 1956, (11), 52–57). [In Russian]. Equilibrium concentrations of oxygen in Fe–Mn melts necessary for the calculation of the activity coefficient from the mass law equation, and experimental confirmation of literature data on the influence of Mn on the O_2 solubility in liquid iron were carried out. The results obtained indicated a sharp difference in the behaviour of Mn in steel-making processes in comparison with other deoxidizing elements. Despite being a comparatively weak deoxidant Mn possesses a high vapour pressure and at liquid steel temperatures it forms, over the surface of metal, a vapour film which, at above 0·2% Mn, consists mainly of Mn atoms. As was shown in the present investigation, Mn vapours react with gaseous O_2 even at insignificant concentrations of the latter in the gaseous phase. Therefore, specific features of Mn behaviour in liquid steel appear more clearly when the surface of the metal is not protected by slag, i.e., during intensive boiling, tapping and casting of steel.—V. G.

Effect of Nickel on High-C High-Cr Die Steel. S. Koshiba. (*Tetsu to Hagane*, 1957, **43**, Mar., 404). [In Japanese]. The effects of Ni in the range 0·12–1·58% on steel containing 2·15% C and 13·5% Cr is shown, as regards transformation during heating, and dimensional changes and hardness during tempering of 950° C oil-cooled specimens.—K. E. J.

Effects of Small Amounts of Aluminium on Some Mechanical Properties of Ferrite Containing Nitrogen. P. Flament. (*Rev. Mét.*, 1957, **54**, July, 537–554). Tests on ingots cast *in vacuo* have shown the importance of C in solution or in cementite or pearlite on elasticity; the Fe-C-N-Al system is also studied with 0·007–0·05% C, 0·002–0·015% N and 0·001–0·035% Al in solution. It is concluded that neither the dissolved Al or AlN affect E or R values but fixation of FeO in Al_2O_3 increases Σ and A. Dissolved Al does not affect rate of diffusion of C to α-iron, nor grain size but AlN increases the range of grain size and tends to produce refining. Small quantities of dissolved Al do not affect ageing after deformation. AlN above a certain limit supresses brittleness due to cold-working and improves stamping quality. The best qualities are attained by treatment at 900° C (below A_3), air-cooling without annealing (which produces further embrittlement).

The Effects of Rare Earth Metals in Iron and Steel. M. G. Stora. (*Echo Mines*, 1957, April, 211–212). A brief historical account of the use of mischmetal in cast iron and steels. (4 references).

The damping capacity, measured by ultrasonics is greatly influenced by the quantity, size, shape and distribution of graphite particles enclosed in the matrix. A new numerical determination of damping capacity is given. Ultrasonic testing for damping capacity may be carried out satisfactorily and quickly, even on small specimens, without any difficulties.

Ultrasonic Inspection in the Oil-Refining and Related Industries. D. J. Evans. (*Non-Destructive Test.*, 1957, **15**, May-June, 156–160). Measurement of steel plate thickness from one side, as in tanks and pipelines, and flaw and crack detection in shafts and in seam testing are reviewed.

Ultrasonic Transmission Tester. J. D. Ross and R. W. Leep. (*Non-Destructive Test.*, 1957, **15**, May-June, 152–154). A device for transmitting and counting pulses for abnormal attenuation is described and its use for examining the bonding of Al to U fuel elements explained.

Supervision of Production by Means of Non-destructive Tests. H. Kostzewske. (*Metall*, 1957, **11**, July, 582–586). The methods here surveyed comprise televised radiography, thickness measurement by X- and γ-rays and by pneumatic means, with digital indication, X- and γ-ray level indication, ultrasonic eddy current and inductive methods.—J. G. W.

Some Practical Aspects of X-Ray Examination of Steel Castings. R. Kottra. (*Kohászati Lapok*, 1955, **10**, *Ontöde*, Sept., 197–205). A short review is given of the X-ray and γ-ray examination of steel castings of 70–600 mm wall thickness, using an electron gun for the former and radioactive isotopes for the latter purposes. Afterwards a comprehensive review is given of a Hungarian method of X-ray examination of steel castings, using normal 250Kv equipment. This method is applicable to the determination of sand inclusions, blow-holes, gas bubbles, cracks and shrinkage cavities. Examples are given.—P. K.

The Use of Multiple-Film Techniques to Speed Industrial Radiographic Inspection. R. E. Turner. (*Non-Destructive Test.*, 1957, **15**, May-June, 146–150). The use of 2 or 3 films of different speeds to record detail in parts of different thicknesses is described.

Approximate Method for the Calculation of Exposure Values in Gamma-Radiography Using Iridium 192 and Caesium 137. W. H. Papke. (*Schweissen u. Schneiden*, 1957, **9**, July, 349–353). The author discusses the various factors that determine the exposure values in gamma-radiography with ^{192}Ir and ^{137}Cs. He presents a nomogram for the radiography of steel. The nomogram consists of two parts; one of them has to be cut out and slid over the other.—T. G.

On the Theory of Gauge Measurement by Absorption Radiography. W. Dahl. (*Stahl u. Eisen*, 1957, **77**, June 27, 884–886). This is a review of work published by A. M. Bogatschew, B. J. Werchowsky, and A. N. Makarow in *Sawodskaja Laboratorija*, 1955, **21**, 808, on the relation of error in gauge measurement and the inherent inaccuracy in the determination of the intensity of the radioisotopes. Equations and diagrams for the correct determination of the gauge are derived.—T. G.

Industrial Uses of Radio-Isotopes. E. N. Shaw. (*Overseas Eng.*, 1957, **31**, Sept., 60–62). A review of applications including thickness gauging and furnace level indicators.

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Influence of Addition of Copper on the Characteristics of an Elinvar Type Alloy "Co-Elinvar." I. Alloys Containing 5% Copper. H. Masumoto, H. Saito and Y. Sugai. (*Sci. Rep. Res. Inst. Tohoku Univ.*, 1957, **9**, June, 171–175). Thermal expansion, rigidity modulus and its temperature coefficient are studied. Copper has little effect, but it narrows the range of minimum thermal expansion. Some alloys high in chromium have a rigidity modulus above 8×10^3 kg/cm².

On the Activities of Manganese and Carbon in Molten Fe–Mn–C Alloys. M. Ohtani. (*Tetsu to Hagane*, 1957, **43**, Mar., 294–295). [In Japanese]. Data are given relating to the activity of Mn in molten Fe–Mn–C alloys at about 1530° C, for several carbon contents between zero and saturation.

The Influence of Manganese on the Activity and Solubility of Oxygen in Liquid Iron. V. V. Averin, R. A. Karasev, A. Yu. Polyakov and A. M. Samarin. (*Izvest. Akad. Nauk, S.S.S.R., Otdelenie Tekh. Nauk*, 1956, (11), 52–57). [In Russian]. Equilibrium concentrations of oxygen in Fe–Mn melts necessary for the calculation of the activity coefficient from the mass law equation, and experimental confirmation of literature data on the influence of Mn on the O_2 solubility in liquid iron were carried out. The results obtained indicated a sharp difference in the behaviour of Mn in steel-making processes in comparison with other deoxidizing elements. Despite being a comparatively weak deoxidant Mn possesses a high vapour pressure and at liquid steel temperatures it forms, over the surface of metal, a vapour film which, at above 0·2% Mn, consists mainly of Mn atoms. As was shown in the present investigation, Mn vapours react with gaseous O_2 even at insignificant concentrations of the latter in the gaseous phase. Therefore, specific features of Mn behaviour in liquid steel appear more clearly when the surface of the metal is not protected by slag, i.e., during intensive boiling, tapping and casting of steel.—V. G.

Effect of Nickel on High-C High-Cr Die Steel. S. Koshiba. (*Tetsu to Hagane*, 1957, **43**, Mar., 404). [In Japanese]. The effects of Ni in the range 0·12–1·58% on steel containing 2·15% C and 13·5% Cr is shown, as regards transformation during heating, and dimensional changes and hardness during tempering of 950° C oil-cooled specimens.—K. E. J.

Effects of Small Amounts of Aluminum on Some Mechanical Properties of Ferrite Containing Nitrogen. P. Flament. (*Rev. Mét.*, 1957, **54**, July, 537–554). Tests on ingots cast *in vacuo* have shown the importance of C in solution or in cementite or pearlite on elasticity; the Fe-C-N-Al system is also studied with 0·007–0·05% C, 0·002–0·015% N and 0·001–0·035% Al in solution. It is concluded that neither the dissolved Al or AlN affect E or R values but fixation of FeO in Al_2O_3 increases Σ and A. Dissolved Al does not affect rate of diffusion of C to α-iron, nor grain size but AlN increases the range of grain size and tends to produce refining. Small quantities of dissolved Al do not affect ageing after deformation. AlN above a certain limit supresses brittleness due to cold-working and improves stamping quality. The best qualities are attained by treatment at 900° C (below A_3), air-cooling without annealing (which produces further embrittlement).

The Effects of Rare Earth Metals in Iron and Steel. M. G. Stora. (*Echo Mines*, 1957, April, 211–212). A brief historical account of the use of mischmetal in cast iron and steels. (4 references).

Carbon Steel: Semifinished for Forging; Hot Rolled and Cold Finished Bars; Hot Rolled Deformed Concrete Reinforcing Bars. (*Amer. Iron Steel Inst. Steel Prod. Man.*, 1957, July, pp. 64).

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Answer to K. P. Bunin, Ya. N. Malinochka and Yu. N. Taran. K. I. Vashchenko and L. M. Sofroni. (*Liteinoe Proizvodstvo*, 1957, (1), 24–27). [In Russian]. Numerous experimental data are presented in this refutation of the criticisms of Bunin et al. (see previous abstract) on the authors' recent articles on graphite formation in Mg-inoculated grey iron.—S. K.

On the Theory of Graphitisation of Cast Iron and Steel. I. V. Salli. (*Izvest. Akad. Nauk, S.S.S.R. Otdelenie Tekn. Nauk*, 1957, (12), 106–116). [In Russian]. Experimental data obtained during studies of phase transformations taking place on the surface of cast iron and steel during thermal treatment *in vacuo* are described.—V. G.

On the Influence of Deformation on Graphitisation of Iron Alloys. K. P. Bunin, S. N. Ivanov. (*Izvest. Akad. Nauk, S.S.S.R. Otdelenie Tekh. Nauk*, 1956, (10), 3–14). [In Russian]. The influence of deformation on graphitization of white, Mg-inoculated cast iron was investigated. It was shown that acceleration of graphitization after deformation is primarily due to the formation of microcracks and defects in the crystals of the matrix. It was established that the formation and growth of the graphite nuclei takes place rapidly in microcracks at the beginning of annealing and is further accelerated by a high concentration of defects and cracks in the matrix. It was shown that in a strongly deformed cast iron the shape of graphite inclusions formed during annealing is determined by the shape of microcracks and the structure of the metallic matrix. On the basis of an analysis of the results obtained, it is concluded that the velocity of growth of graphite inclusions in iron alloys is limited not by the diffusion of carbon, but by the process of removal of atoms of the matrix from the front of graphitization.—V. G.

Fundamental Studies on Spheroidal Graphite Cast Iron. XIX. Influence of Tellurium on the Formation of Spheroidal Graphite. R. Ozaki. (*Tetsu to Hagane*, 1957, **43**, Mar., 206–207). [In Japanese].—K. E. J.

The Graphitization Determining Factor in the Light of Certain Experiments. N. G. Girshovich. (*Liteinoe Proizvodstvo*, 1956, (11), 14–18). [In Russian]. The author outlines two prevalent points of view on the graphitization process and describes some experiments designed to answer the crucial question of whether self-diffusion is the determining factor in graphitization. The experiments showed that the course and rate of graphitization are not affected by the presence of numerous artificial holes in the casting, thus contradicting the self-diffusion theory; practical experience leading to the same conclusion is cited. This, together with an investigation of the effect of temperature on the process indicates the correctness of the view that graphitization is the result of the normal growth of graphite nuclei in the matrix.—S. K.

Fundamental Studies on Spheroidal Graphite Cast Iron. XVIII. Influence of Manganese on the Formation of Spheroidal Graphite. R. Ozaki. (*Tetsu to Hagane*, 1957, **43**, Mar., 205–206). [In Japanese]. The effects of Mn and Si, added as Fe–Mn and Fe–Si in various amounts, on Swedish iron (analysis given) are reported.—K. E. J.

The Effect of Small Amounts of Elements on the Formation of Spheroidal Graphite in Cast Iron. T. Tottori. (*Tetsu to Hagane*, 1957, **43**, Mar., 209–211). [In Japanese]. The effects of Ti in varying amounts, alone and in conjunction with Sb, Pb and Bi are reported.—K. E. J.

Influence of Various Elements on the Graphitisation of High-Carbon Steel. K. Kusaka. (*Tetsu to Hagane*, 1957, **43**, Mar., 411–413). [In Japanese]. The effect of soluble Al on the graphitization of high-carbon steel, (*a*) austenitized and water-quenched and (*b*) cold-drawn with 35·4% reduction, is shown for various heat-treatments. The effects of Sn, Te, Zr, Cr, Nb, W, Mo, V, Ti, Si and Mn on graphitization after cold-working are also shown.—K. E. J.

The Effects of Silicon and Chromium on the Position and Range of Eutectoid Temperatures [of Spheroidal Graphite Iron]. S. Drapal. (*Hutnické Listy*, 1957, **12**, (9), 769–777). Austenite formation starts preferentially in the central portions of dendrites and the amount existing in the eutectoid range increases with rising temperature. With increase in Si the temperatures rise and the range extends with approximately a parabolic relationship. Cr lowers the upper eutectoid temperature and raises the lower one, the relationship is not linear and depends on Si content.

Investigation on Cast Iron Having Fine Graphite Produced by Melting Cast Iron Covered with Slag Containing TiO_2. IX. Investigation on the Net Structure and the Estimation of Micro-hardness of S-H Cast Iron. M. Tsuda. (*Tetsu to Hagane*, 1957, **43**, 283–285). [In Japanese]. The "net" structure on the fracture of the iron is examined at different magnifications, and micro-hardness values are given for both the austenite dendrites and eutectic graphite structure from several specimens. Calculated micro-hardness figures are given for comparison.—K. E. J.

Thermodynamic Considerations in the Effect of Additions on the Graphitization of Cast Iron. S. Drapal. (*Hutnické Listy*, 1957, **12**, (8), 683–687). The effect of various elements on the stability of cementite complexes such as $(Fe, Mn)_3C$ is investigated from known thermodynamic relationships. Free energy is used as a criterion of stability. It appears that Cr and Mn should increase and Co and Ni decrease its stability. This agrees with practical experience.

On the Controlling Process in Iron–Cobalt Alloys. G. N. Kadykova and Ya. P. Selisskii. (*Fizika Metallov i Metallovedenie*, 1956, **3**, (3), 486–496). [In Russian]. The object of the investigation was to obtain experimental data of the kinetics in the binary alloy Fe–Co with V and Cr contents. After cold deformation and tempering, these steels harden between 250–550°. A further increase in temperature causes a decrease of hardness. This is explained by the regulating process resulting from cold distortion and from the noticeable extra stress. The consequences of the hardening must show themselves in a combination of the first stages of the regulating process and the process of reversion when the residual stresses are slowly removed.—L. H.

On the Rate of the Controlling Process in Fe–Co Alloys. G. N. Kadykova and Ya. P. Selisskii. (*Fizika Metallov i Metallovedenie*, 1956, **3**, (3), 497–502). The construction of an arrangement for hardening in a gas current allowed the rapid cooling of specimens of 50 mm length suitable for the measurement of electrical resistance. In the investigation of He as a hardening medium the regulating speed of cooling ranged between 100 and 10,000°/sec. The experiments showed the necessity for a speed of cooling of over 6000°/sec for maintaining the constancy of the solid solution Fe–Co with more than 50% Co.—L. H.

Physical Methods of Studying Slowly Occurring Transformations in High Alloy Steel. Ya. S. Gintsburg, Yu. M. Margolin and A. F. Sachavskii. (*Zavodskaya Laboratoriya*, 1956, **22**, (9), 1046–1052). [In Russian]. An account is given of the application of magnetic and X-ray structural methods in conjunction with chemical phase analysis for the detailed study of the high temperature ageing process in high alloy steel. With non-magnetic steels this combined approach was found to enable even very slight structural changes to be studied. With such steels the magnetic method was generally more sensitive than the X-ray, but not with ferromagnetic steels. Curves showing changes in various properties of steels during ageing are presented.—S. K.

The Determination of Hardening Properties in Unalloyed and Lightly Alloyed Steels. E. Greulich. (*Wire*, 1957, Apr., 11–14). The half-time period at the temperature of maximum rate of austenite conversion is measured. C60 and FD7 steels were used and the determination and checking of the characteristic no. which is the ln of the half-period are described.

Carbide Precipitation in Low Carbon Steels. A. Oolbekkink. (*Metalen*, 1957, **12**, July 15, 244–247). [In Dutch]. The author examines the case of a low-carbon alloy steel (0·03%) and finds that in spite of contrary expectations even this carbon content is not low enough to avoid undesirable carbide precipitation. It is shown that after heating for an hour at 650° C followed by furnace cooling, sufficient carbides precipitate to cause the corrosion resistance of the steel to be seriously affected as is proved by corrosion tests. However, when welding such steels, critical temperature is held for too short a time for precipitation to take place. Thus this material possesses several advantages over that having higher carbon content.—F. B. H.

Isothermal Decomposition of Austenite in Steels Alloyed with Tungsten. III. Effect of Tungsten on the Isothermal Decomposition of Austenite in Hypoeutectoid Carbon Steel. J. Čadek and K. Mazanec. (*Hutnické Listy*, 1957, **12**, (9), 777–788). Steel with ~ 0·4% C was examined. The formation of eutectoid containing the carbide M_3C (with 4·3

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On the Mechanism of the Formation of Spheroidal Graphite in Cast Iron. I. E. Bolotov, V. I. Syreishchikova and S. G. Guterman. (*Fizika Metallov i Metallovedenie*, 1957, **4**, (1), 177–180). [In Russian]. Results are here presented of experiments aimed to establish a connection between the appearance of spheroidal graphite in cast iron and its treatment for the removal of S and O from the melt. Iron, Si and electrodes of graphitic carbon were melted in a vacuum in a graphite crucible at 1400° at $2 \cdot 10^{-3}$ mm pressure, and then cooled in a vacuum. Microscopic examination of the cast iron revealed graphite crystals of spheroidal form. Detailed results of the experiments are given together with tabulated data.—L. H.

On the Problem of the Formation of Graphite in Grey Magnesium Cast Iron. K. P. Bunin, Ya. N. Malinochka and Yu. N. Taran. (*Liteinoe Proizvodstvo*, 1957, (1), 22–23). [In Russian]. The authors produce evidence to support their contention that although the results reported by K. I. Vashchenko and L. M. Sofroni (*Ibid.*, 1955, (7), and (11)) are interesting, their treatment was incorrect. They further claim that some of their experimental methods were wrong and that their conclusions contradicted their own results as well as those obtained by other workers on the mechanism of graphite formation in Mg-inoculated cast iron. The examples given suggest that the hardening procedure adopted in the work cited did not secure the crystallization in the form of ledeburite of all the liquid present at the moment of hardening.

Answer to K. P. Bunin, Ya. N. Malinochka and Yu. N. Taran. K. I. Vashchenko and L. M. Sofroni. (*Liteinoe Proizvodstvo*, 1957, (1), 24–27). [In Russian]. Numerous experimental data are presented in this refutation of the criticisms of Bunin et al. (see previous abstract) on the authors' recent articles on graphite formation in Mg-inoculated grey iron.—S. K.

On the Theory of Graphitisation of Cast Iron and Steel. I. V. Salli. (*Izvest. Akad. Nauk, S.S.S.R. Otdelenie Tekn. Nauk*, 1957, (12), 106–116). [In Russian]. Experimental data obtained during studies of phase transformations taking place on the surface of cast iron and steel during thermal treatment *in vacuo* are described.—V. G.

On the Influence of Deformation on Graphitisation of Iron Alloys. K. P. Bunin, S. N. Ivanov. (*Izvest. Akad. Nauk, S.S.S.R. Otdelenie Tekh. Nauk*, 1956, (10), 3–14). [In Russian]. The influence of deformation on graphitization of white, Mg-inoculated cast iron was investigated. It was shown that acceleration of graphitization after deformation is primarily due to the formation of microcracks and defects in the crystals of the matrix. It was established that the formation and growth of the graphite nuclei takes place rapidly in microcracks at the beginning of annealing and is further accelerated by a high concentration of defects and cracks in the matrix. It was shown that in a strongly deformed cast iron the shape of graphite inclusions formed during annealing is determined by the shape of microcracks and the structure of the metallic matrix. On the basis of an analysis of the results obtained, it is concluded that the velocity of growth of graphite inclusions in iron alloys is limited not by the diffusion of carbon, but by the process of removal of atoms of the matrix from the front of graphitization.—V. G.

Fundamental Studies on Spheroidal Graphite Cast Iron. XIX. Influence of Tellurium on the Formation of Spheroidal Graphite. R. Ozaki. (*Tetsu to Hagane*, 1957, **43**, Mar., 206–207). [In Japanese].—K. E. J.

The Graphitization Determining Factor in the Light of Certain Experiments. N. G. Girshovich. (*Liteinoe Proizvodstvo*, 1956, (11), 14–18). [In Russian]. The author outlines two prevalent points of view on the graphitization process and describes some experiments designed to answer the crucial question of whether self-diffusion is the determining factor in graphitization. The experiments showed that the course and rate of graphitization are not affected by the presence of numerous artificial holes in the casting, thus contradicting the self-diffusion theory; practical experience leading to the same conclusion is cited. This, together with an investigation of the effect of temperature on the process indicates the correctness of the view that graphitization is the result of the normal growth of graphite nuclei in the matrix.—S. K.

Fundamental Studies on Spheroidal Graphite Cast Iron. XVIII. Influence of Manganese on the Formation of Spheroidal Graphite. R. Ozaki. (*Tetsu to Hagane*, 1957, **43**, Mar., 205–206). [In Japanese]. The effects of Mn and Si, added as Fe–Mn and Fe–Si in various amounts, on Swedish iron (analysis given) are reported.—K. E. J.

The Effect of Small Amounts of Elements on the Formation of Spheroidal Graphite in Cast Iron. T. Tottori. (*Tetsu to Hagane*, 1957, **43**, Mar., 209–211). [In Japanese]. The effects of Ti in varying amounts, alone and in conjunction with Sb, Pb and Bi are reported.—K. E. J.

Influence of Various Elements on the Graphitisation of High-Carbon Steel. K. Kusaka. (*Tetsu to Hagane*, 1957, **43**, Mar., 411–413). [In Japanese]. The effect of soluble Al on the graphitization of high-carbon steel, (*a*) austenitized and water-quenched and (*b*) cold-drawn with 35·4% reduction, is shown for various heat-treatments. The effects of Sn, Te, Zr, Cr, Nb, W, Mo, V, Ti, Si and Mn on graphitization after cold-working are also shown.—K. E. J.

The Effects of Silicon and Chromium on the Position and Range of Eutectoid Temperatures [of Spheroidal Graphite Iron]. S. Drapal. (*Hutnické Listy*, 1957, **12**, (9), 769–777). Austenite formation starts preferentially in the central portions of dendrites and the amount existing in the eutectoid range increases with rising temperature. With increase in Si the temperatures rise and the range extends with approximately a parabolic relationship. Cr lowers the upper eutectoid temperature and raises the lower one, the relationship is not linear and depends on Si content.

Investigation on Cast Iron Having Fine Graphite Produced by Melting Cast Iron Covered with Slag Containing TiO_2. IX. Investigation on the Net Structure and the Estimation of Micro-hardness of S-H Cast Iron. M. Tsuda. (*Tetsu to Hagane*, 1957, **43**, 283–285). [In Japanese]. The "net" structure on the fracture of the iron is examined at different magnifications, and micro-hardness values are given for both the austenite dendrites and eutectic graphite structure from several specimens. Calculated micro-hardness figures are given for comparison.—K. E. J.

Thermodynamic Considerations in the Effect of Additions on the Graphitization of Cast Iron. S. Drapal. (*Hutnické Listy*, 1957, **12**, (8), 683–687). The effect of various elements on the stability of cementite complexes such as $(Fe, Mn)_3C$ is investigated from known thermodynamic relationships. Free energy is used as a criterion of stability. It appears that Cr and Mn should increase and Co and Ni decrease its stability. This agrees with practical experience.

On the Controlling Process in Iron–Cobalt Alloys. G. N. Kadykova and Ya. P. Selisskii. (*Fizika Metallov i Metallovedenie*, 1956, **3**, (3), 486–496). [In Russian]. The object of the investigation was to obtain experimental data of the kinetics in the binary alloy Fe–Co with V and Cr contents. After cold deformation and tempering, these steels harden between 250–550°. A further increase in temperature causes a decrease of hardness. This is explained by the regulating process resulting from cold distortion and from the noticeable extra stress. The consequences of the hardening must show themselves in a combination of the first stages of the regulating process and the process of reversion when the residual stresses are slowly removed.—L. H.

On the Rate of the Controlling Process in Fe–Co Alloys. G. N. Kadykova and Ya. P. Selisskii. (*Fizika Metallov i Metallovedenie*, 1956, **3**, (3), 497–502). The construction of an arrangement for hardening in a gas current allowed the rapid cooling of specimens of 50 mm length suitable for the measurement of electrical resistance. In the investigation of He as a hardening medium the regulating speed of cooling ranged between 100 and 10,000°/sec. The experiments showed the necessity for a speed of cooling of over 6000°/sec for maintaining the constancy of the solid solution Fe–Co with more than 50% Co.—L. H.

Physical Methods of Studying Slowly Occurring Transformations in High Alloy Steel. Ya. S. Gintsburg, Yu. M. Margolin and A. F. Sachavskiĭ. (*Zavodskaya Laboratoriya*, 1956, **22**, (9), 1046–1052). [In Russian]. An account is given of the application of magnetic and X-ray structural methods in conjunction with chemical phase analysis for the detailed study of the high temperature ageing process in high alloy steel. With non-magnetic steels this combined approach was found to enable even very slight structural changes to be studied. With such steels the magnetic method was generally more sensitive than the X-ray, but not with ferromagnetic steels. Curves showing changes in various properties of steels during ageing are presented.—S. K.

The Determination of Hardening Properties in Unalloyed and Lightly Alloyed Steels. E. Greulich. (*Wire*, 1957, Apr., 11–14). The half-time period at the temperature of maximum rate of austenite conversion is measured. C60 and FD7 steels were used and the determination and checking of the characteristic no. which is the ln of the half-period are described.

Carbide Precipitation in Low Carbon Steels. A. Oolbekkink. (*Metalen*, 1957, **12**, July 15, 244–247). [In Dutch]. The author examines the case of a low-carbon alloy steel (0·03%) and finds that in spite of contrary expectations even this carbon content is not low enough to avoid undesirable carbide precipitation. It is shown that after heating for an hour at 650° C followed by furnace cooling, sufficient carbides precipitate to cause the corrosion resistance of the steel to be seriously affected as is proved by corrosion tests. However, when welding such steels, critical temperature is held for too short a time for precipitation to take place. Thus this material possesses several advantages over that having higher carbon content.—F. R. H.

Isothermal Decomposition of Austenite in Steels Alloyed with Tungsten. III. Effect of Tungsten on the Isothermal Decomposition of Austenite in Hypoeutectoid Carbon Steel. J. Čadek and K. Mazanec. (*Hutnické Listy*, 1957, **12**, (9), 777–788). Steel with ~ 0·4% C was examined. The formation of eutectoid containing the carbide M_3C (with 4·3

and 9% W) is accompanied by an increase of C in the untransformed austenite. The rate of growth of eutectoid depends on time at a given temperature and the activation energy was calculated to be 62,000 cal/g atom and rate of growth appears to be diffusion-controlled. Segregation of W does not appear to control the stability of austenite where decomposition begins with the eutectoid reaction.

The Effect of Austenite Dissociation on the Speed of Hydrogen Diffusion in Steels. P. A. Ryabov and P. V. Gel'd. (*Fizika Metallov i Metallovedenie*, 1957, **4**, (1), 189–190). [In Russian]. Experiments on three sorts of steel are described. The results obtained show that the process of elimination of H_2 from Cr–Ni steels depends essentially on the process of cooling and on the isothermal periods in the stages 1 and 2 of the austenitic transformation. This problem is of great interest in connection with the H_2 brittleness of steels.—L. H.

The Redistribution of Carbon during the Transformation of Austenite in the Central Regions. L. I. Kogan and R. I. Entin. (*Fizika Metallov i Metallovedenie*, 1957, **4**, (2), 360–368). [In Russian]. This experimental study examined the relation of the chemical composition of steels, of the temperature and of the duration of the transformation of the austenite, to the redistribution of carbon. A dozen different kinds of steel have been examined and the data obtained are set out in detail.—L. H.

On the Mechanism of Intermediate Transformation of Austenite. B. A. Leont'ev and L. S. Palatnik. (*Izvest. Akad. Nauk. S.S.S.R. Otdelenie Tekh. Nauk*, 1956, (10), 28–35). [In Russian]. Electron-microscopical investigations of the structure of steels 30KhMA, 55S2 and ShKh15 (chemical compositions given) indicated that the decomposition in the intermediate range for all three steels was initiated by the α-phase. In the lower temperature range, supersaturation of the α-phase with carbon was observed, while this was absent in the upper range. The formation of low carbon α-phase in the process of the intermediate transformation can be explained by the formation of nuclei deficient in carbon fluctuations and their coherent growth during preliminary removal of carbon from the boundary. Depending on the degree of alloying of austenite and the temperature of transformation, the growth of ferrite zones is accompanied by an enrichment of surrounding austenite in carbon or by the formation in the latter of carbides. Autoinhibition of the intermediate transformation is observed during the inhibition of carbide formation in austenite.—V. G.

Structural Non-Uniformity of Micrograins of Austenite at High Temperatures. V. I. Prosvirin. (*Izvest. Akad. Nauk, S.S.S.R., Otdelenie Tekh. Nauk*, 1956, (9), 117–120). [In Russian]. Some experimental data were obtained indicating that heating a solid solution of complex composition to a high temperature does not decrease chemical non-uniformity in micrograins, but on the contrary increases it, leading to a noticeable layering of the solution. Specimens from an austenitic steel (0·1% C, 23% Cr, 35% Ni, 1·2% Ti, 1·2% Nb, 0·6% Mo, 1% V), were used for the investigation.—V. G.

X-Ray Method for Determining Residual Austenite with the Use of Graded Clearing of the Comparison Lines. B. A. Brusilovskii. (*Zavodskaya Laboratoriya*, 1956, **22**, (8), 936–943). [In Russian]. An account is given of an X-ray spectral method for the determination of residual austenite in steels, particularly hardened steels, with martensite in the structure; the method can also be used for other purposes in quantitative X-ray phase analysis. A device consisting of a series of Al plates of graded thickness was arranged before the region of the film on which the lines whose intensities were to be compared were focused; this enabled a visual comparison of darkening to be made. The factor limiting the speed of the method is the duration of the exposure.—S. K.

The Activating Influence of Plastic Deformation on the Martensite Transformation. G. V. Kurdyumov, O. P. Maksimova and A. J. Nikonorova. (*Doklady Akad. Nauk, S.S.S.R.*, 1957, **114**, (4), 768–771). [In Russian]. Two alloy samples were studied: C 0·03, Cr 18·1, Ni 8·1% and C 0·05, Cr 17·2, Ni 9·1%. The samples were subjected to deformation at different temperatures and the activating and retarding influences of deformation on the transformation of austenite into martensite were studied.—S. I. T.

Studies of Ball Bearing Steels. VIII. Behaviour of Carbides in Ball Bearing Steels by Electrolytic Isolation. M. Ueno and H. Nakajima. (*J. Mech. Lab.*, 1957, **11**, May, 108–113). Conclusions are that ball bearing steels contain ~15% cementite; Cr, Mn and V are higher in the cementite than in the matrix and Ni is lower, 98% and 95% were found in the case of Cr. Heated above A_1, Cr and V increase with quenching temp., while Mn falls at first and rises later. Quenching is usual from 820–840°, undissolved cementite is then 7–9%. Comparisons of SKF with a Japanese steel were made.

Study on Carbides in Practical Special Steels by Electrolytic Isolation. III. On Carbides in Several Construction Steels. T. Sato, T. Nishizawa and M. Ohashi. (*Tetsu to Hagane*, 1957, **43**, Mar., 485–489). [In Japanese]. Results are given showing the concentrations of the alloying elements in the carbides or the matrices for Ni-Cr, Cr-Mo and Si-Mn constructional steels, in the annealed condition and as tempered at various temperatures.—K. E. J.

Contribution to the Study of Non-Metallic Inclusions in Ferro-chrome. R. Zoja. (*Met. Steel*, 1957, **49**, March, 206–211). [In Italian]. The author studies the morphology of inclusions in refined ferro-chrome, and the isothermal transformations of inclusions in this alloy. He extends his investigations to allied fields starting from the molten ferro-alloy.

Growth of Voids in Metals during Diffusion and Creep. R. W. Balluffi and L. L. Seigle. (*Acta Met.*, 1957, **5**, Aug., 449–454). Thermodynamic conditions for growth of voids from suitable nuclei have been studied and applied to intergranular void formation observed during creep and also during Kirkendall diffusion. Vacancy supersaturation and stress are then discussed.

Solution of Ferrite in Grey Cast Iron by Heat Treatment. N. Hajtó. (*Kohászati Lapok*, 1954, **9**, May, 102–104). The ferrite in grey cast iron will be dissolved in austenite at 900° C and higher temperatures, but it precipitates again during air cooling even in thin castings.—P. K.

Mechanism of Solubilization and Graphite in Cast Iron. V. Gottardi. (*Met. Ital.*, 1957, **49**, March, 173–180). [In Italian]. In the first part the author studies the solubilization of graphite in the austenite of a ferritic spheroidal cast iron by microscope and microhardness determination. It is shown that the rate of solution varies according to the degree of perfection of the nodules and that austenization is particularly rapid along the boundaries of ferritic grains. Microhardness measurements show that carbon diffuses around the nodules proportionally to time and temperature. In the second part of the paper the author studies isothermal graphitization at 725° C on lamellar and spheroidal pearlitic cast iron and shows that graphite nodules and flakes act as attraction centres of the graphite which separates at the boundaries because of the decomposition of the carbides. (22 references).—M. D. J. B.

Grain Boundary Carbides in Extra-Low-Carbon Stainless. R. O. Steiner and P. S. Trozzo. (*Metal Progress*, 1957, **72**, July, 108–110). Cr-Ni stainless steels become sensitive to intergranular corrosion after heating at 800–1400°F and this is due to carbide precipitation at grain boundaries. This is usually remedied by addition of Nb or Ti but may also be treated by keeping C to 0·03% max. but even below this intergranular precipitates have been observed. Electron micrographic and other studies show that a carbide $(Fe, Cr)_{23}C_6$ is formed and a narrow, rapid-etching zone is associated. Carbon is enriched in the area and appears to have diffused from the grain.

The Effect of Tungsten on the Interlamellar Spacing of Pearlite. K. Mazanec. (*Hutnické Listy*, 1957, **12**, (4), 309–315). [In Czech]. The interlamellar spacing was measured in three typical structural steels of the Cr-W-V type. It was found to increase by 42% as the W content of the steels was increased from 0·42 to 1·5%. Theoretical aspects of the effect are discussed.—P. F.

The Theory of the Decomposition of Austenite. R. F. Mehl. (*Rev. Mét.*, 1957, **54**, Apr., 245–256). Aspects of the theory of nucleation and growth processes in the decomposition of austenite are discussed in detail. The theory of nucleation, the role of diffusion, the influence of the free energy change of the various reactions, capillarity, the structure and energy of interfaces between phases and the structure and energy of the grain boundary and crystal imperfections are all considered as factors determining the rate of decomposition and the morphology of the crystals formed.—B. G. B.

The Effect of Nitrogen on the Hardenability of Carbonitrided Surfaces and the Isothermal Decomposition of Austenite. B. Přenosil. (*Hutnické Listy*, 1957, **12**, (4), 289–299). [In Czech]. Jominy tests were carried out on consecutive

parallel layers of test pieces which had either been carburized with charcoal and barium carbonate, or carbonitrided in a mixture of propane and ammonia. Hardenability in the hardened layer is increased if the N_2 content reached 0·3–0·4%; with higher percentages there is no corresponding gain in relation to the hardness as found in the as-carburized state. In fact N_2 tends to retard the decomposition of austenite, i.e. the incubation time of the transformation is increased.

The Effect of Heat-Treatment Cycle on the Stability of Supercooled Austenite. E. S. Tovpenets. (*Stal'*, 1957, (7), 642–643).

Nucleation Sites of Bainitic Carbides in Alloy Steels. S. M. Kaufman, G. M. Pound and H. I. Aaronson. (*J. Met.*, 1957, **9**, July, Section 2, 855–856). Bainitic carbides formed in a plain C hypoeutectoid steel nucleate entirely within ferrite at higher temperatures and in both ferrite and austenite at lower temperatures, the effect of alloying elements is now studied and nucleation in both austenite and ferrite is observed.

Occurrence of the Beta-Manganese Structure in Transition Metal Alloys and Some Observations on Chi-Phase Equilibria. H. J. Goldschmidt. (*Metallurgia*, 1957, **56**, July, 17–26). Fe-Cr-W, Fe-Cr-Mo and Fe-Cr-W-C systems are considered.

Structural Relation and Equilibria between the ϵ and ζ Phases of the Fe-N System. A. Burdese. (*Met. Ital.*, 1957, **49**, March, 195–199). [In Italian]. Equilibria between the ϵ and ζ phases of the Fe-N System and the structure of ϵ solids are discussed. The structure can be reduced to the special group D_3–C 312 with 6 Fe atoms in 6 (K) and 3 N atoms in 1 (*a*), 2 (*d*). For solids of a maximum degree of nitridation 98·5% of these positions are occupied by N atoms. Experimental results indicate that when the N_2 content is low these positions can be only partially occupied.—M. D. J. B.

CORROSION

A Study of Metallic Corrosion With the Aid of the Heavy Oxygen Isotope. I. Moist Atmosphere Corrosion of Iron. A. I. Brodskii, A. S. Fomenko and T. M. Abramova. (*Zhur. Fiz. Khim.*, 1956, **30**, (3), 676–684). Shavings of ST-2 steel were used in 3% $MgCl_2$ solutions with O_2 passing through. Microflotation and mass spectrographic analyses were carried out and the O_2 in the corrosion products examined by hydrogenation. The mechanism $O_2 + 2H_2O + 4e \rightarrow 4OH^-$ was supported. Total O_2 balance also agreed.

A Photoelectric Study of Oxidized Chromium, Nickel, and Chrome–Nickel Steel in Alkaline Solution. I. B. Rabinovich and V. I. Veselovskii. (*Zhur. Fiz. Khim.*, 1956, **30**, Feb., 313–320). The effect of light during anodic polarization was investigated. A considerable potential drop occurs on irradiation, up to 325 mV for Cr and 230 mV for Ni. The photogalvanic effect is of a sensitizing nature, light is absorbed by the oxide and decomposition occurs of the potential-determining complex.

Corrosion: Types and Prevention. C. L. Hibert. (*Product Eng.*, 1956, **27**, Mid-Oct., C6–C11). A brief review is given of corrosive attack, both chemical and electro-chemical, and the visible forms of corrosion are described. The action of electro-chemical corrosion is discussed in detail, and details are also given of various corrosive preventatives.—E. A. C.

On the Corrosion of Malleable Iron. N. Tsutsumi. (*Rep. Castings Res. Lab. Waseda Univ.*, 1956, Oct., 19–23). [In English]. Laboratory testing, consisting of total immersion in 2% HCl, 0·5% brine, 5% acetic acid and 10% HNO_3, and e.m.f. measurements, did not demonstrate the higher resistance of cast or malleable iron to corrosion than steel. There seems to be no experimental method to give quantitative results comparable with those obtained under service conditions.—K. E. J.

Events at a Scratch-Line. U. R. Evans. (*Bull. Inst. Met. Finishing*, 1957, **7**, Summer, 139–166). A lecture. A scratch line engraved under a definite load is used as a reproducible coating defect and corrosion arising from it is studied. Phenomena observed are described including the effects of ageing in air before wetting and the influence of internal stress produced by scratching.

The Determination of Intercrystalline Corrosion in Welded and Un-welded Austenitic Chromium–Nickel Steels. H. Zitter. (*Arch. Eisenhüttenwesen*, 1957, **28**, July, 401–416). The effect of duration of test on the temperature limits within which intercrystalline corrosion occurs in a steel with 0·07% C, 18% Cr, and 8% Ni has been investigated by means of the Huey test, the rapid test in a $HF–HNO_3$ mixture and the Strauss-Hatfield test in a $CuSO_4–H_2SO_4$ mixture.—L. J. L.

How Copper Affects the Sulphurization-resistant Property of Cast Iron at High Temperatures. M. Shiozawa and H. Nakai. (*Rep. Castings Res. Lab. Waseda Univ.*, 1956, Oct., 17–18). [In English]. The resistance of cast iron to attack by H_2S at 900° C is improved by additions of copper up to 2%, but the effect is reversed with larger amounts. This is explained on the basis of a greater affinity of Cu than iron for S above 700° C, leading to formation of CuS as the Cu dissolves in iron, and replacement of iron in FeS by Cu. Cu then diffuses outwards to form a loose surface film. This is confirmed by the electron diffraction examination of a sulphurized film, which shows a structure approximately to $CuFeS_2$.—K. E. J.

A Study of the Aggressivity of Water. E. Gimenez San Martin. (*Dyna*, 1957, **32**, Apr., 208–215). [In Spanish]. Methods of analysis for the impurities and gases present in natural waters are described and followed by a description of the mechanisms of corrosion and abrasion caused by them. A table that gives the relationship between variables in water composition and aggressivity is included.—P. S.

The Storage of High Purity Water. R. R. Diesk. (*Corrosion*, 1957, **13**, Sept., 585–588). New protective measures for steel tanks are studied, including paints, rubber and metallic coatings. Tests suggested the suitability of Al and four 44,000-gal tanks were constructed. Electrochemical findings on the film produced in tap, distilled and demineralized waters are reported.

Water Conditions for High Pressure Boilers. D. E. Voyles and E. C. Fiss. (*Corrosion*, 1957, **13**, Sept., 589–590). Studies on high-purity water are reported with regard to corrosiveness and factors in boiler operation.

Eight Years of Experience with Austenitic Steel Piping Materials at Elevated Steam Conditions. F. P. Fairchild. (*Amer. Soc. Mech. Eng., Preprint*, 56–A–181, 1957, pp. 9). Use of 347 steel in several power stations is recorded.

Note on the Corrosion of Steel and the Treatment of Water for Boilers. T. Songa. (*Met. Ital.*, 1957, **49**, May, 371–376). [In Italian]. The characteristic features of corrosion in boiler plants and the various factors related to corrosion are described and analysed. A critical examination is made of the various water treatment processes in the light of experience gained at the Breda Institute. (30 references).—M. D. J. B.

Examination of the Cause of Cracks on the Tubes of the Vogelbusch Distillation Boiler Used in Hungarian Factories for Alumina. I. Kurovsky. (*Kohászati Lapok*, 1954, **9**, Jan., 27–34). The author found the cause of the cracks in the caustic embrittlement of tubes exterior dia. 38 mm, wall thickness 2·5 mm, made of steel C 0·15–0·22%, Cu 0·5% max, Mo 0·04–0·33%, Cr up to 0·1%. The embrittlement was furthered by the hardening effect of normalizing as well as by the stresses derived from the cold widening of one end of the tubes to 39 mm. To avoid such cracking the use of steel deoxidized with Al and without susceptibility to ageing and also annealing below 700° C instead of normalizing are suggested.—P. K.

Corrosion of Metals in Buildings. The Corrosion of Ferrous Metals in Buildings. J. C. Hudson and F. Wormwell. (*Chem. Ind.*, 1957, Aug. 10, 1078–1089). Many examples of corrosion of railings, gutters, window frames, girders and joists, prefabricated members, water services, boilers, radiators, ventilation ducts, steel fireplaces and cupboards are described and discussed.

Corrosion of Metals in Buildings. The Corrosion of Metals in Contact with Concrete. P. E. Halstead. (*Chem. Ind.*, 1957, Aug. 24, 1132–1137). Corrosion of steel reinforcement and its prevention are included.

Corrosion of Metals in Buildings. The Performance of Zinc and Zinc Coatings. R. W. Bailey and H. G. Ridge. (*Chem. Ind.*, 1957, Sept. 14, 1222–1227). Corrosion exposed to the atmosphere, painting of zinc, roofs and exterior work and zinc-coated steel inside buildings are reviewed. Also zinc in contact with water supplies, sewage, bimetallic systems, contact with wood, cement and mortar, asphalt and roofing felt or mosses, and underground locations are briefly considered.

Corrosion Tests with Sintered Iron. A. Bukowiecki and U. A. Eugster. (*Schweiz. Arch. Wiss. Tech.*, 1957, **23**, March, 78–83). Distilled water and a 3% solution of NaCl were used as the corroding media. It was shown experimentally that sintered iron corroded more rapidly than steel plate of the same composition. The corrosion rate increases with increase in porosity

of the sinter. The corrosive action of distilled water is minimized by mineral oils.—R. P.

Corrosion of Metals by Hygroscopic Particles. A. Bukowiecki. (*Schweiz. Arch. Wiss. Techn.*, 1957, **23**, April, 97–104). Water-soluble salts and hygroscopic materials cause corrosion of metals provided that the absolute atmospheric moisture is greater than the vapour pressure of the saturated solution in question, unless the latter acts as an inhibitor. Silica gel and similar materials cause corrosion only if they contain water-soluble non-inhibiting impurities. (14 references).—R. P.

Corrosion—Its Implications in Aircraft. R. Tate. (*Chem. Ind.*, 1957, Apr. 27, 506–508). Corrosion of steel parts of engines, exhausts and undercarriages is discussed.

Corrosion and Food Manufacture. J. W. Selby. (*Corrosion Prevention and Control*, 1957, **4**, Sept., 37–40, 46). A review of materials in contact with foods, including the use of stainless steel equipment, is given.

Corrosion in Maritime Atmospheres. G. Bolognesi. (*Rivista Mecc.*, 1957, **8**, April 13, 13–16). [In Italian]. A brief review is given of the effects of marine atmosphere on steel structures. Methods of preventing corrosion are discussed.—M. D. J. B.

The Effect of Production Technology on the Corrosion Resistance of Pit Ropes. E. Hila and J. Teindl. (*Hutnik*, 1957, **7**, (5), 158–161). [In Czech]. The liability of ropes to corrosion is ascribed to several causes originating in the processes of patenting, drawing, heat-treating, greasing, as well as in actual use. The nature of these causes and methods for preventing their occurrence are discussed.—P. F.

Corrosion Problems in the Oil Refinery. J. Tourret. (*Corrosion et Anti-Corrosion*, 1956, **4**, Dec., 389–399). Corrosion problems are reviewed in the storage tanks for petroleum products, in thermal and catalytic cracking distillation units, in refining units and gas treatment units. Typical corrosion effects are illustrated and discussed. Non-ferrous corrosion is included.

Coating Resistance Conforms to Probability Law. F. E. Kulman. (*Corrosion*, 1957, **13**, Sept., 553–554). Measurements on buried pipes are shown to follow the normal probability curve.

The Corrosion of Metals at High Temperatures by Vanadium Pentoxide. Note III. Effect of Al and Si on the Corrosion Resistance of Ni–Cr Steels. V. Cirilli and A. Burdese. (*Met. Ital.*, 1957, **49**, May, 320–326). [In Italian]. The authors consider V_2O_5–SiO_2–Al_2O_3 systems. They show that in a first system no intermediate compounds are formed whereas in the second the orthovanadate $AlVO_4$ is formed with incongruent melting at 695° C (± 10°). Between $AlVO_4$ and V_2O_5 the authors show the existence of a eutectic corresponding to 30% of alumina melting at 640° C (± 5°). On the basis of these results the authors discuss the behaviour of Ni–Cr steels containing small quantities of Al and Si in the presence of V_2O_5.—M. D. J. B.

The Corrosion of Single Crystals and Recrystallized Single Crystals of Iron and Steel in Citric Acid. W. R. Buck and H. Leidheiser jun. (*J. Electrochem. Soc.*, 1957, **104**, Aug., 474–481). Studies in 0·2 M acid at 20° and at the b.p. were made on discs and spheres of Armco iron and type L steel. Quantitative measurements were made on (100) and (321) faces, respectively the slowest and most rapid corroding forms. Various forms of polishing and machining were used. Polycrystalline material corrodes more rapidly than single crystals. Stannous ion greatly reduces corrosion rate.

Electrochemical Polarization. II. Ferrous–Ferric Electrode Kinetics on Stainless Steel. M. Stern. (*J. Electrochem. Soc.*, 1957, **104**, Sept., 559–563). The data support theoretical equations for the system, applying to reversible and to corroding electrodes. The possibility of determining anode-to-cathode area ratios for corroding metals is discussed.

Stress-Corrosion Cracking Problems in the Homogeneous Reactor Test. E. G. Bohlman and G. M. Adamson. (*Amer. Soc. Mech. Eng., 2nd Nuclear Eng. and Sci. Conference*, 1957, 57–NGSC–111, pp. 21). Chloride-induced cracking in an austenitic stainless steel reactor was encountered, in a secondary leak-detecting system contaminated during manufacture. It is shown that oxygenated uranyl sulphate solutions do not produce cracking in absence of chloride.

Selective Corrosion of a Carbon Steel. P. Csokán. (*Kohászati Lapok*, 1954, **9**, May, 114–116). Examination of the selective corrosion of a clamping tool of about 0·45% C steel was carried out in chromic acid electrolyte. The cause of the corrosion was the anodic solution of pearlite.—P. K.

The Corrosion of Puddled Iron. N. Collari. (*Calore*, 1957, **28**, April, 147–153). [In Italian]. This article described the particular properties of puddled iron which give it its curious corrosion characteristics where layers of resistant and quickly corroding zones alternate. The effects of Cu, Ni and P are discussed, together with the probable speed of corrosion of puddled iron in comparison with steel.

Corrosion in Light Oil Storage Tanks. E. H. Tandy. (*Corrosion*, 1957, **13**, July, 427–432). Factors governing corrosion are O_2 solubility, rate of working, type of roof, vapour pressure and climatic conditions. Observations are recorded and a corrosion mechanism discussed. Control is considered and vapour space effects, temperature effects and plate thickness corrosion allowance are noted.

The Corrosion of Steel in Petroleum Distilling Plant. P. Csokán. (*Kohászati Lapok*, 1956, **11**, Feb., 55–62). The author analysed the chemical composition of the corrosion products of steels used in an oil distilling plant, and determined the lattice of the compounds of the scale layers by a semi-quantitative X-ray method. He also examined them metallographically. The chemical constitution of the process is given according to the theory of Akimov and the mechanism of corrosion is described.—P. K.

The Corrosion of Iron in High-Temperature Water. I. Corrosion Rate Measurements. II. Kirkendall Experiments. D. L. Douglas and F. C. Zyzes. (*Corrosion*, 1957, **13**, June, 361–374; July, 433–436). A new method is described using small autoclaves containing He. Afterwards the gas is analysed by mass spectrometer and H_2 calculated. It was used for Armco iron at 240–360° C. Superheated and saturated vapours and dilute solutions were also studied. Kirkendall-type experiments are described to identify iron species diffusing through magnetite films. A slurry of ^{62}NiO was painted on iron discs and decrease measured and interpreted as outward diffusion of ionised iron.

Differential Aeration Corrosion of Superheater Elements. (*Brit. Eng. Boiler Elec. Ins. Techn. Rep.*, 1957, **3**, 57–58). Perforation of elements in a water-tube boiler is described.

Anodic Behaviour of Iron in Acid Solutions. M. Stern and R. M. Roth. (*J. Electrochem. Soc.*, 1957, **104**, June, 390–392). Measurements by a technique already described were made in 4% NaCl acidified to pH 1·5 by two methods. The iron used contained 0·01% S, and polarization data are plotted and also potential as a function of applied cathodic current. The calculations for the two sets of measurements are indicated and the mechanism is discussed. Change in anode area is the explanation favoured.

Some Aspects of Corrosion Processes of Iron, Copper and Aluminium in Ethylene Glycol Coolant Fluids. P. F. Thompson and K. F. Lorking. (*Corrosion*, 1957, **13**, Aug., 531–535). Effect of triethanolamine phosphate inhibitor is also studied, it coordinated with Cu which was transferred to Fe and Al and caused local corrosion.

Some Unusual Effects of Hydrogen in Corrosion Reactions. J. E. Draley and E. W. Ruther. (*J. Electrochem Soc.*, 1957, **104**, June, 329–333). Corrosion in presence of water is considered to be due to diffusion of H-ion through protective layers forming H_2 molecules beneath them. Diffusion into the metal may occur, gaseous H_2 may form or a hydride may be produced. Examples are given, the mechanism is not of universal application.

Failure of Steel-Admiralty Duplex Condenser Tubes by Hydrogen Penetration. H. E. Honkala and E. A. Wright. (*Corrosion*, 1957, **13**, Aug., 501–504). Failure in propane condensers is described due to exposure to H_2S. Laboratory studies are described.

Formation of Scales on Steel Tubes in a Hydrocarbon Atmosphere. R. Hantos, F. Köves and N. Torma. (*Kohászati Lapok*, 1956, **11**, March, 105–107). The chemical and metallographic examination of scales on seamless tubes has shown that these defects originate from the carburizing effect of a CH_4 atmosphere in oil heating.—P. K.

Factors in the Selection of Corrosion-Resistant Materials. F. L. Whitney jun. (*Metal Progress*, 1957, **71**, June, 90–96). The ease of fabrication, rate of corrosion and initial cost are important items in the selection of materials but the influence of temperature, concentration, purity and velocity of the corrosive fluid, erosion by sludge and concentration cells under adhering solids are shown to affect considerably the rate of corrosion and are not always measured under conventional test conditions.—B. G. B.

Using Stainless Steel for Corrosion Resistance. R. Paret. (*Machine Design*, 1956, **28**, Oct. 18, 114–121). This article describes kinds of corrosion and types of stainless steel, it also summarizes considerations to prevent corrosion in the design, fabrication and operation of stainless steel products.

Corrosion-Resistant Structural Materials. H. T. Francis. (*Machine Design*, 1956, **28**, May 31, 104–107). Corrosion-prevention methods, existing and new materials, and basic design principles and practices in selecting suitable materials are discussed.—M. A. K.

An Example of the Effect of Initial Surface Condition on Resistance to Corrosion. (*Brit. Eng. Boiler Elec. Ins. Techn. Rep.*, 1957, **3**, 85–87). Corrosion in a steel tank due to mill scale is reported.

Examination of the Corrosion Resistance of Inoculated Grey Iron to Acids and Alkalies. F. Varga and K. Jánossy. (*Kohászati Lapok*, 1954, **9**, Dec., 275–280). Corrosion experiments in concentrated and dilute acids as well as in alkaline liquors shows that the main condition for high corrosion resistance is a homogeneous and dense, pure pearlitic structure. Small size of graphite and high tensile strength generally improve the resistance against chemical attack. The corrosion resistance of grey irons inoculated with CaSi is rather higher than that of those inoculated with FeSi. The solution rate depends on the time and increases in some solutions or decreases in others with increase of time.

Corrosion Resistance of No. 20 and No. 20 Cb Stainless-Steel Welds. H. C. Campbell, T. J. Moore and S. E. Tyson. (*Welding J.*, 1957, **36**, Aug., 353s–359s). Weld-cracking and nitric, sulphuric and HNO_3-HF acid corrosion tests are reported. No. 20 Cb is subject to less severe attack than No. 20. Annealing at 1950° F is preferred but treatment at 1700° F for 2 h followed by quenching is satisfactory.

Austenitic Cr-Fe-Ni Alloys Resistant to Stress Corrosion Cracking in Magnesium Chloride. H. Uhlig, A. White and J. Lincoln jun. (*Acta Met.*, 1957, **5**, Aug., 473–475). Cracking in boiling 42% $MgCl_2$ solution was studied and compositions have been developed that do not crack for a week or more. Compositions of Ni-Cr steels and the effects of C and N are noted. Mechanism is discussed.

Chloride and Caustic Stress Corrosion of Austenitic Stainless Steel in Hot Water and Steam. W. L. Williams. (*Corrosion*, 1957, **13**, Aug., 539–545). Factors are discussed and complete control cannot be assured by control of composition, temp. or stress level within practical limits. The effect of Cl-ion depends on O_2 and either may be limited. Stress corrosion by caustic is less well understood but a proper phosphate–caustic ratio may be a suitable measure.

Corrosion-fatigue Cracking at the Feed Inlet to a Locomotive-type Boiler. (*Brit. Eng. Boiler Elec. Ins. Techn. Rep.*, 1957, **3**, 76–78). Notch-brittleness following corrosion cracking is described.

Intergranular Cracking, Corrosion and Manufacturing Defects in the Tubes of a Water-tube Boiler. (*Brit. Eng. Boiler Elec. Ins. Ltd. Techn. Rep.*, 1957, **3**, 79–84). Three types of defects occurring together are described.

Explosion of a Vertical Boiler due to Corrosion-Fatigue. (*Brit. Eng. Boiler Elec. Ins. Techn. Rep.*, 1957, **3**, 9–33). Failure due to a corrosion-fatigue fissure underneath the internal lap edge of the vertical seam in the shell plate is described. **Further Examples of Caustic and other Cracking in the Riveted Seams of Steam Boilers.** (34–53). Eight cases are described and structures shown.

Corrosion Tests for Plated Parts. (*Steel*, 1957, **140**, June 17, 108–109). Two accelerated corrosion tests for plated coatings, particularly exterior car parts, are described. In the "Corrodkote" test, the plate is made wettable by rubbing with a kaolin paste and then subjected to a high humidity atmosphere. The other test uses an atomized spray containing acetic acid. Accelerated corrosion tests for anodic films are also mentioned.—D. L. C. P.

Electrochemical Processes in Stress Corrosion. H. Gerischer. (*Werkstoffe Korrosion*, 1957, **8**, July, 394–401). Simple model systems are examined and two factors are recognized. The localization of corrosion is related to plastic deformation where the surface atoms are activated by slip planes or deformed grain boundaries and to the cracking of passivated surfaces. It is explained how these processes can be demonstrated by the anodic corrosion currents.

On the Service Life of Lead Bath Pots. H. Krautmacher and W. Püngel. (*Stahl u. Eisen*, 1957, **77**, June 27, 837–845). Laboratory tests on the corrosion rate of a variety of steels by lead showed that the corrosion rate depends mainly on the temperature and not so much on time. Killed O.H. steel was considerably more resistant than rimming O.H. steel. Heat resistant Cr and Ci-Ni steels are highly corrosion-resistant against liquid lead even at high temperatures. The authors suggest the use of cladded pots.—T. G.

Some Instances of Intergranular Penetration of Steel by Molten Copper. (*Brit. Eng. Boiler Elec. Ins. Techn. Rep.*, 1957, **3**, 161–171). Three cases are described, one in a boiler tube that failed owing to overheating, one in a water-tube boiler economizer at defective welds and the case of a steel bolt used to join copper strips between the poles of a synchronous motor.

Cathodic Protection of Oil Well Casings at Kettleman Hills, California. J. K. Ballou and F. W. Schremp. (*Corrosion*, 1957, **13**, Aug., 507–514). Tests on three casings showed protection to be effective at least to 8000 ft. Current densities of 1–1·5 ma/ft² seem to be necessary. Methods of measurement are given for casing potential which indicates degree of protection with reasonable accuracy.

ANALYSIS

Bismuthate Method of Determining Chromium in Steels not Containing Vanadium. P. F. Agafonov. (*Zhur. Anal. Khim.*, 1956, **11**, (6), 752–753). [In Russian]. Conditions of quantitative oxidation of Cr by sodium bismuthate are given. The reaction was applied for a rapid determination of Cr in steels with satisfactory results. The analytical procedure is described in some detail.—V. G.

On the Detection of Cobalt. K. N. Bagdasarov, P. N. Kovalenko and S. S. Mel'nikova. (*Zhur. Anal. Khim.*, 1957, **12**, (4), 564–565). Thiosulphate, thiourea or even careful drying on filter paper detects cobalt by the blue colour.

Photometric Determination of Cobalt with Various Pyrazolones. E. V. Sokolova, A. S. Pesis and N. I. Panova. (*Zhur. Anal. Khim.* 1957, **12**, (4), 489–494). Diantipyrinylmethanes are used.

Potentiometric Micro-Titration of Manganese in Ferrous and Non-Ferrous Metals and Alloys, In Ores, Rocks and Other Materials. A. S. Slovatinskii. (*Zhur. Anal. Khim.*, 1957, **12**, (4), 485–488). Permanganate is used in weakly acid pyrophosphate.

Determination of Sulphides and Oxides of Manganese in Carbon Steels, and Their Separation from Manganese Carbides. N. F. Leve. (*Zavodskaya Laboratoriya*, 1955, **21**, (9), 1032–1035). [In Russian]. The investigation establishes what happens to the manganese carbides in the analysis of non-metallic inclusions in steels, and what is their influence on the determination of sulphides and oxides of Mn. The supposition that Mn carbides decompose during electrolysis is correct only in cases of simple carbides of the type Mn_3C which form hydroxides in water and give complex solutions with citric or tartaric acid salts. The process is fully described and results of tests tabulated.—L. H.

Detection of Nickel in Presence of Cobalt, Copper and Other Elements. A. D. Shun'ko. (*Zhur. Anal. Khim.*, 1957, **12**, (4), 569). Dimethylglyoxime is used.

Determination of Silicon in the Presence of Phosphorus, Iron, Copper, Manganese and Titanium. V. N. Galakhova. (*Zhur. Anal. Khim.*, 1957, **12**, (4), 499–503). The vanadic–molybdic complexes are studied. Si cannot be determined in the presence of 0·5 mg P or more.

Determination of Titanium in Ferrotitanium by Amperometric Titration with Cupferron. Yu. I. Usatenko, G. E. Bekleshova, E. I. Grenberg, M. Ya. Genis and E. E. Karpusha. (*Zavodskaya Laboratoriya*, 1956, **22**, (5), 528–529). [In Russian]. Titration with standard cupferron solution has been found satisfactory for determining titanium in ferrotitanium if the solution titrated is 0·15–0·5 N with respect to acid. With this acidity iron can be combined with Trilon and rendered ineffective for the Fe/Ti ratios of ferrotitanium.

The Determination of Arsenic in Iron and Steel. B.I.S.R.A. Methods of Analysis Committee. (*J.I.S.I.*, 1958, Apr., **188**, 331–337). [This issue].

Use of Anion Exchanges in Analytical Chemistry. III. Separation of Small Amounts of Lead, Zinc, Cadmium, Tin and Bismuth from Copper, Cobalt and Iron. K. Liška and L. Klir. (*Chem. Listy*, 1957, **51**, (8), 1549–1550).

Rapid Analytical Methods for Metals and Minerals. III. Polarographic Determination of Vanadium in Minerals. Z. Šulcek. (*Chem. Listy*, 1957, **51**, (8), 1453–1456).

Rapid Method for Determining Lime in Self-Fluxing Sinter. A. N. Tkachenko and R. A. Geller. (*Zavodskaya Laboratoriya*, 1956, **22**, (5), 543). [In Russian]. A rapid volumetric method has been successfully used for the determination of lime in a sinter having the following composition range: 13–17% SiO_2, 45–50% Fe, 7–14% FeO, 2–3% Mn, 5–15% CaO. The time for a determination is 25–30 min.—S. K.

Rapid Analysis for Determination of Cr_2O_3 and SiO_2 Contents of Chrome Ores by Physical Methods. H. Sövegjarto. (*Radex Rundschau*, 1957, (4), 668–672). A rapid method is described for the determination of Cr_2O_3 and SiO_2 in chrome ores which involves the relationship between the density and chemical composition. The accuracy of the method as used in Austria is $\pm$ 1%. It must be remembered that the relationship mentioned can vary for ores from different deposits.—R. S.

Method by the Instituto Nacional del Carbon for Analysis of Coal Ash (*Inst. Nac. Carbon Bol. Inf.*, 1957, **6**, Jan.-Feb., 22–26). After fusion with Na_2CO_3, Si is determined as SiF_4, Fe with $KMnO_4$, Al by difference from Fe, Al and P_2O_5, Ca as sulphate from oxalate and Mg as pyrophosphate.

Method Used by the Instituto Nacional del Carbon for Determination of Nitrogen by the Semi-micro-Kjeldahl Process. (*Inst. Nac. Carbon Bol. Inf.*, 1957, **6**, Jan.-Feb., 29–31). An apparatus distilling from the flask used for solution is described.

Method Used by the Instituto Nacional del Carbon for Determination of Sulphur in Coal Ash. (*Inst. Nac. Carbon Bol. Inf.*, 1957, **6**, Jan.-Feb., 27–28). Fixed S is determined from the HCl extract of the ash as $BaSO_4$.

Research at the Politecnico of Milan on the Electrochemistry of Metals. R. Piontelli. (*Chem. Ind.*, 1957, Oct. 5, 1304–1309). Polarization curves and the cells for their determination, the kinetics of displacement reactions, the electrochemical behaviour of single crystals, passivity and passivation and current distribution in electrochemical systems are the topics considered.

Voltammetric Behaviour of the Iron (II)–(III) and Cerium (III)–(IV) Couples in Potentiometric Titrations at Constant Current and Amperometric Titrations with Two Indicator Electrodes. I. M. Kolthoff and E. R. Nightingale, jun. (*Anal. Chim. Acta*, 1957, **17**, Sept., 329–338).

Points of Zero Charge of Some Metals and Alloys. B. S. Krasikov and V. V. Sysoeva. (*Doklady Akad. Nauk, S.S.S.R.*, 1957, **114**, (4), 826–828). [In Russian]. This is a study of the potential of zero charge of zinc– and iron–chromium alloys. In the case of Fe–Cr the potential increases with increase of the percentage of Fe up to 30% and then remains constant. Points of zero charge are considered as characteristic constants for a given metal or alloy.—S. I. T.

Variations in the Impedance of Iron in Sulphuric–Chromic Acid Media during Electrochemical Oscillations. L. Gougerot and R. Alfieri. (*J. Chim. Phys.*, 1957, **54**, July-Aug., 514–526). Oscillations occurring in iron in H_2SO_4–H_2CrO_4 solutions are investigated. Impedance varies during the process by a cycle recalling a hysteresis cycle.

Spectral Analysis and Its Role in the Laboratories of the Metallurgical Industry. M. Nicolaid. (*Met. Constr. Masini* 1957, **9**, (5), 49–51). [In Rumanian]. A general investigation of the possibilities of applying spectral analysis for the examination of raw materials, for the control of production and of the finished article. Examples are adduced to show that in many cases the use of spectral analysis is much quicker than chemical analysis.—L. H.

Read Spectrograph Directly for Rapid Analysis. (*Iron Age*, 1957, **180**, Sept. 26th, 124–125). The "Automatic Spectro-Lecteur" of the Radio-Cinema Co., Paris, is described. The average time taken is 1·5 min and a permanent trace is recorded.

Determination of Oxygen in Steels by Spectrum Analysis. O. B. Fal'kova. (*Zavodskaya Laboratoriya*, 1955, **21**, (9), 1083–1087). [In Russian]. Determination of gases in metals can be carried out in two ways. The first is to extract the gases and then to submit them to spectrum analysis, and the second is to extract the gases and at the same time to stimulate them to luminescence with an electrical discharge. The apparatus required is complicated and great difficulties have to be overcome. The experiments describe the use of the ISP–51 spectrograph with a f. = 270 mm and gives full details of its construction and use. Descriptions are given for the determination of oxygen and for the construction of the graphs with tabulation of results. The method adopted was introduced in 1953–4.—L. H.

Spectrum Lines of Cobalt in the Presence of Iron and Nickel. L. A. Bakhmutov. (*Zavodskaya Laboratoriya*, 1956, **22**, (11), 1321–1322). [In Russian]. For the mass analysis of ores, minerals and rocks for Co in the presence of Ni and Fe the spectrum lines are used together with the background radiation. It is claimed that the method is more precise, more efficient and much simpler. It enables the selection of 2 spectrum lines of Co, relatively free from the interference of Fe and Ni. The line usually recommended, 3405.120 is inadvisable owing to the interference of the carbon from the arc.—L. H.

Spectrophotometric Determination of Titanium with Phenylfluorone. V. Damodaran. (*J. Sci. Indust. Res.*, 1957, **16B**, Aug., 366–369). Microgram quantities of quadrivalent Ti can be estimated.

A New Spectrophotometric Determination of Titanium with Sodium Alizarinsulphonate. H. Goto, Y. Kakita and M. Namiki. (*Sci. Rep. Res. Inst. Tôhoku Univ.*, 1957, **9A**, (4), 245–252).

Spectrographic Determination of Impurities in Dolomites and Dinas Rocks. P. A. Koka and G. A. Salomatina. (*Zavodskaya Laboratoriya*, 1955, **21**, (9), 1061–1066). [In Russian]. The author's task consisted in working out a method for the determination of impurities in dolomites and refractory materials in use in the heating units of various industrial plants. The method had to determine Al_2O_3, TiO_2, CaO, MgO and iron oxides. The general proportion of impurities in dolomites is 25–30% whilst in the dinas refractories no longer in use $\sim$ 6%. The apparatus adapted was the ISP 22 spectrograph with a 0·025 mm slit illuminated by a triple lens system with the light from the central part of the arc. The determinations are described in detail and tabulated results of the tests given.—L. H.

Determination of the Carbon Content in the Case-Hardened Layer by an X-Ray Method. M. D. Perkas. (*Zavodskaya Laboratoriya*, 1956, **22**, (9), 1061–1063). [In Russian]. In the method described the C content in the case-hardened layer is found by using the relationship between this and the ratio of the c/a axis in the martensite lattice formed on hardening. The ratio is found by an X-ray method for layers at increasing depths. These layers are successively reached by repeated treatment of the specimen with dilute HNO_3. The suitability of the method for three steels (18 KhNMA, 18 KhGT and 12Kh2N4) gas case-hardened has been demonstrated and the variation of C content with depth for one of them is shown.—S. K.

HISTORICAL

The Structural Use of Iron in Antiquity. 8. B. Hamilton. (*Trans. Newcomen Soc.*, Preprint 1957, Nov. 13, pp. 14). A full discussion of the probability of ancient accounts of large iron structural units in Ancient and Medieval times is presented. No positive conclusion is arrived at, but evidence is presented that the accounts are not impossible.

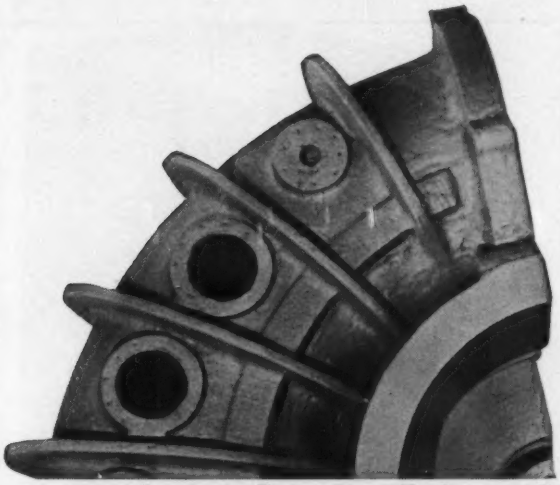
Iron Industry of the Weald. F. Evans. (*Iron Steel*, 1957, **30**, Oct., 469–471). The author traces the history of iron-making in the Weald district from the Middle Ages onwards, and illustrates some of the products.—G. F.

Decorative Etching and the Science of Metals. C. S. Smith. (*Endeavour*, 1957, **16**, Oct., 199–208). The revelation of structure by etching is discussed, mainly in accounts of Ancient and Oriental, particularly Japanese, ironwork.

An 18th Century Precursor of Kelly and Bessemer. M. Weiss. (*Metal Progess*, 1957, **72**, Aug., 77). A brief account of a steel making process described by Réaumur in France in 1722 and by Swedenborg in Sweden in 1734 is given.

Company Histories. I. Dorman Long. C. Wilson. (*Steel Rev.*, 1957, Apr., 11–23).

Forging in the Past. R. C. Benson. (*E.S.C. News*, 1957, **10**, Spring, 4–9). Notes on prehistoric and early historical processes are given, with an account of early hammers and the steam-driven forges of the parent firms of the Sheffield industry.



Half gas circulator casing cast in steel and machined for C. A. Parsons & Co. Ltd. for Nuclear Power Station, Calder Hall. Weight as cast 35 tons. Sectional thickness max 7" min 1¾". Reproduced by permission of C. A. Parsons & Co. Ltd.

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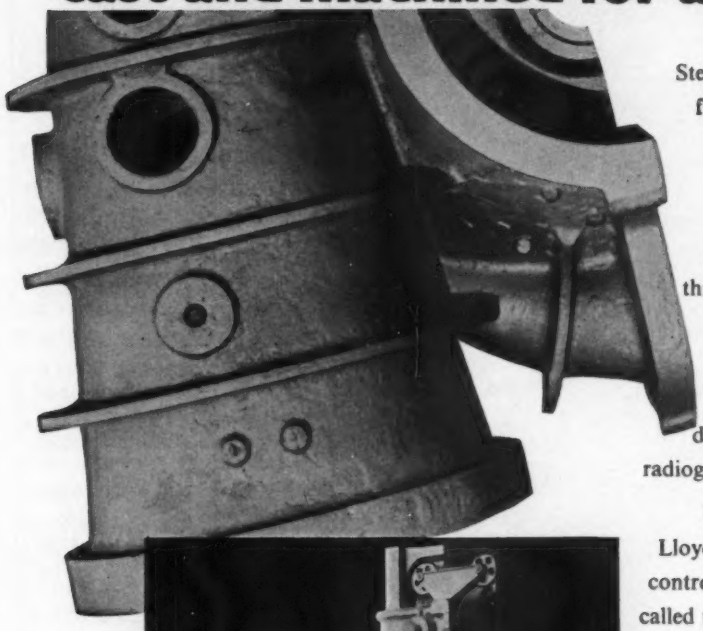

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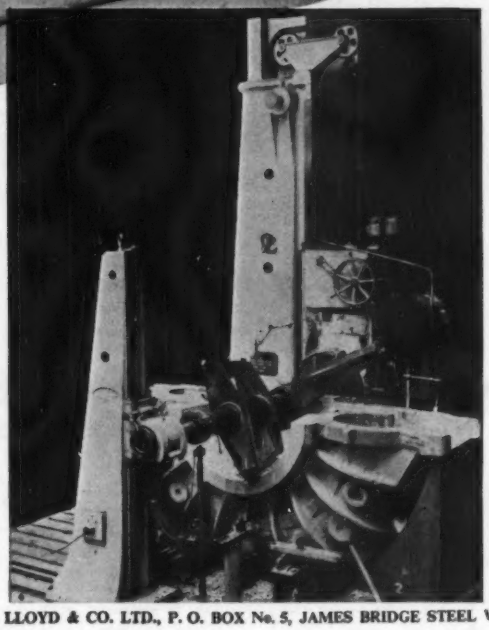

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THE IRON AND STEEL INSTITUTE

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Proceedings of the

FORGEMASTERS' MEETING, 1954

In October, 1954, The Iron and Steel Institute held a Joint Meeting with the National Forgemasters' Association and La Chambre Syndicale de la Grosse Forge Française. Technical Sessions were held in London at which nine papers on forging theory and practice and forging plant were presented and discussed. The remainder of the Meeting comprised visits to the English Steel Corporation Ltd., Thos. Firth and John Brown Ltd., and Hadfields Ltd., in Sheffield.

The Proceedings at the Technical Sessions have now been published as a special Report. The five French papers and discussion are presented in English, but summaries of all the papers are also given in French. The Report, No. 60 in the Special Report series of the Institute, can be obtained from the Offices of the Institute, 4 Grosvenor Gardens, London, S.W.1, price 37*s.* 6*d.* (Members 25*s.*).

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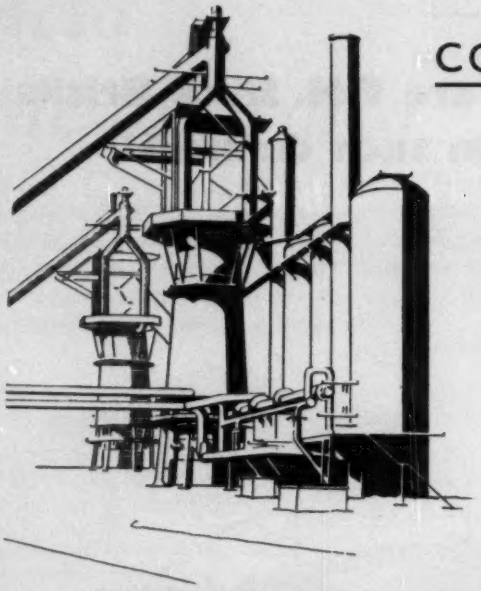

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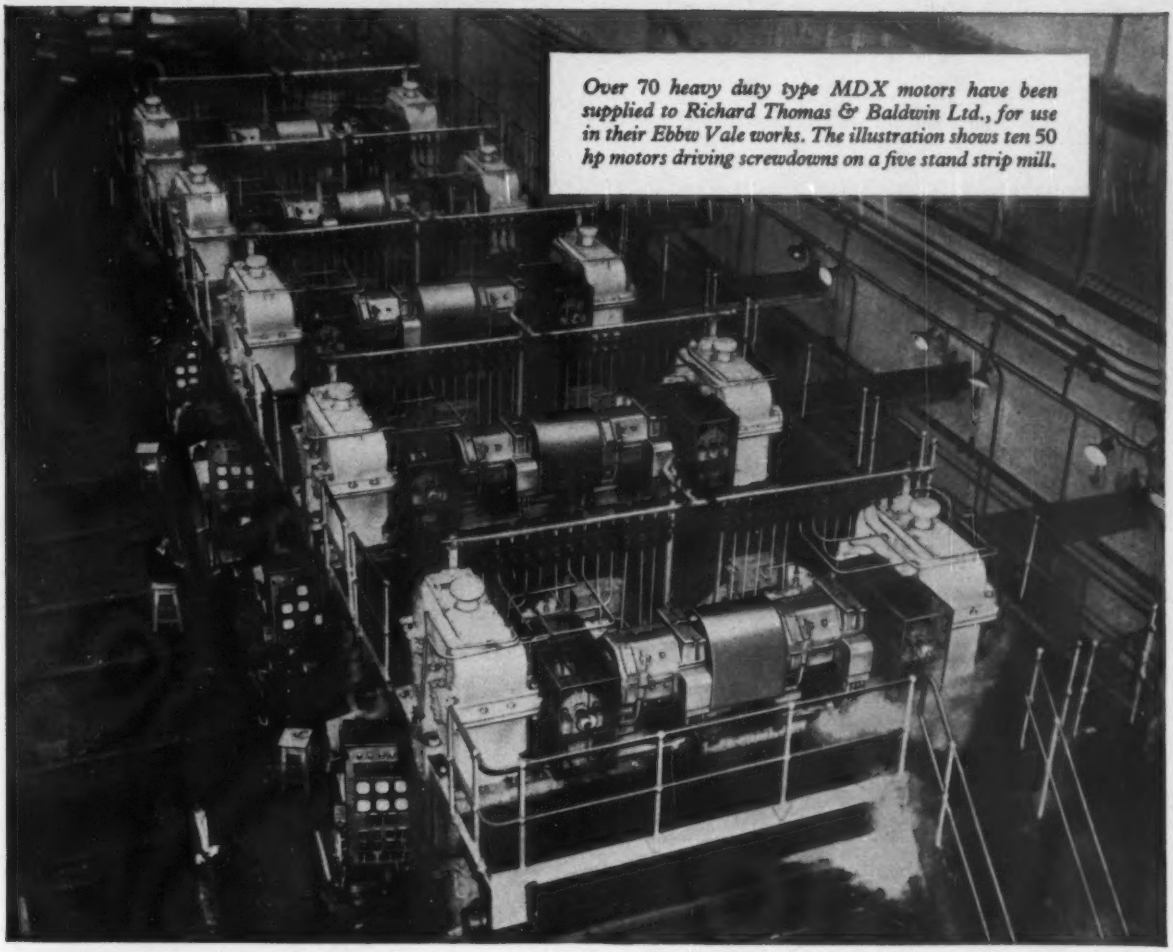

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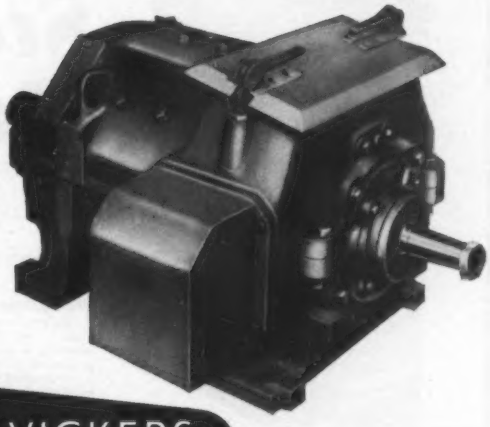

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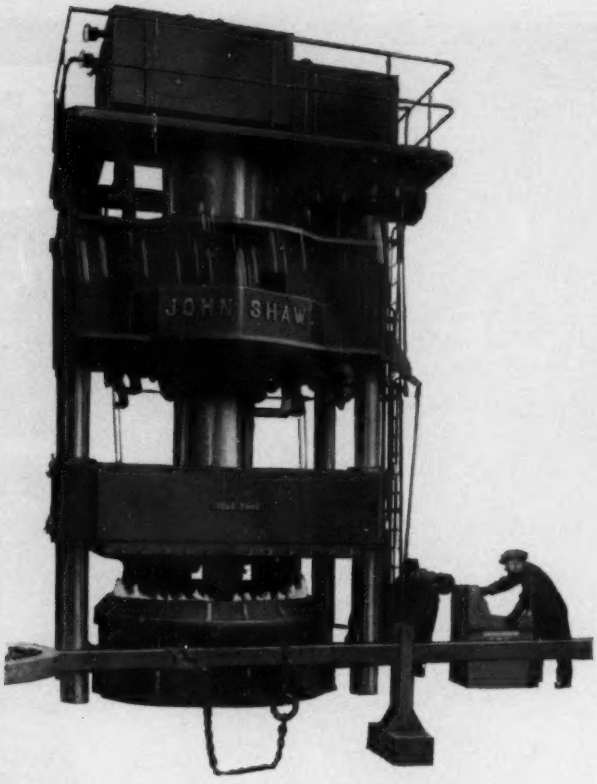

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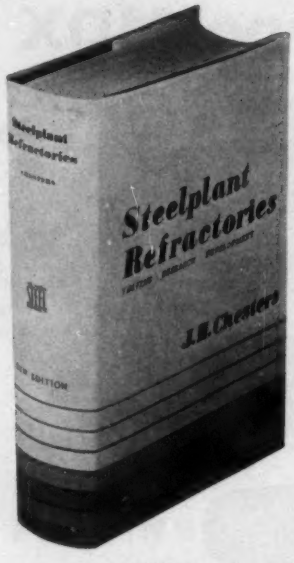

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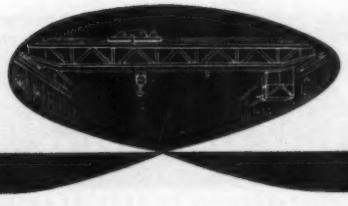

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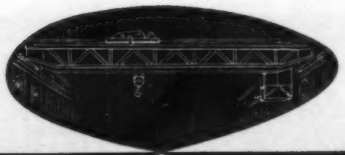

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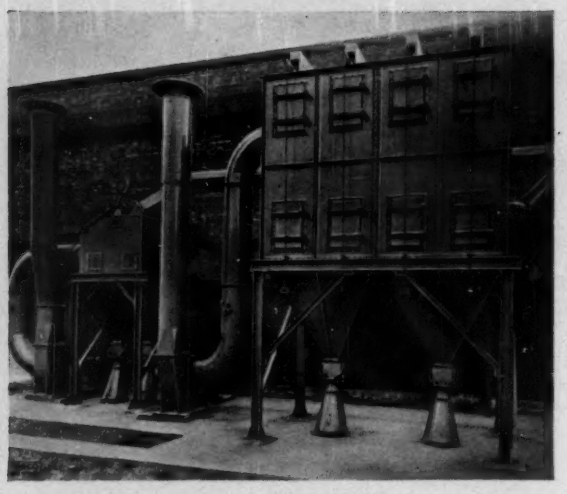

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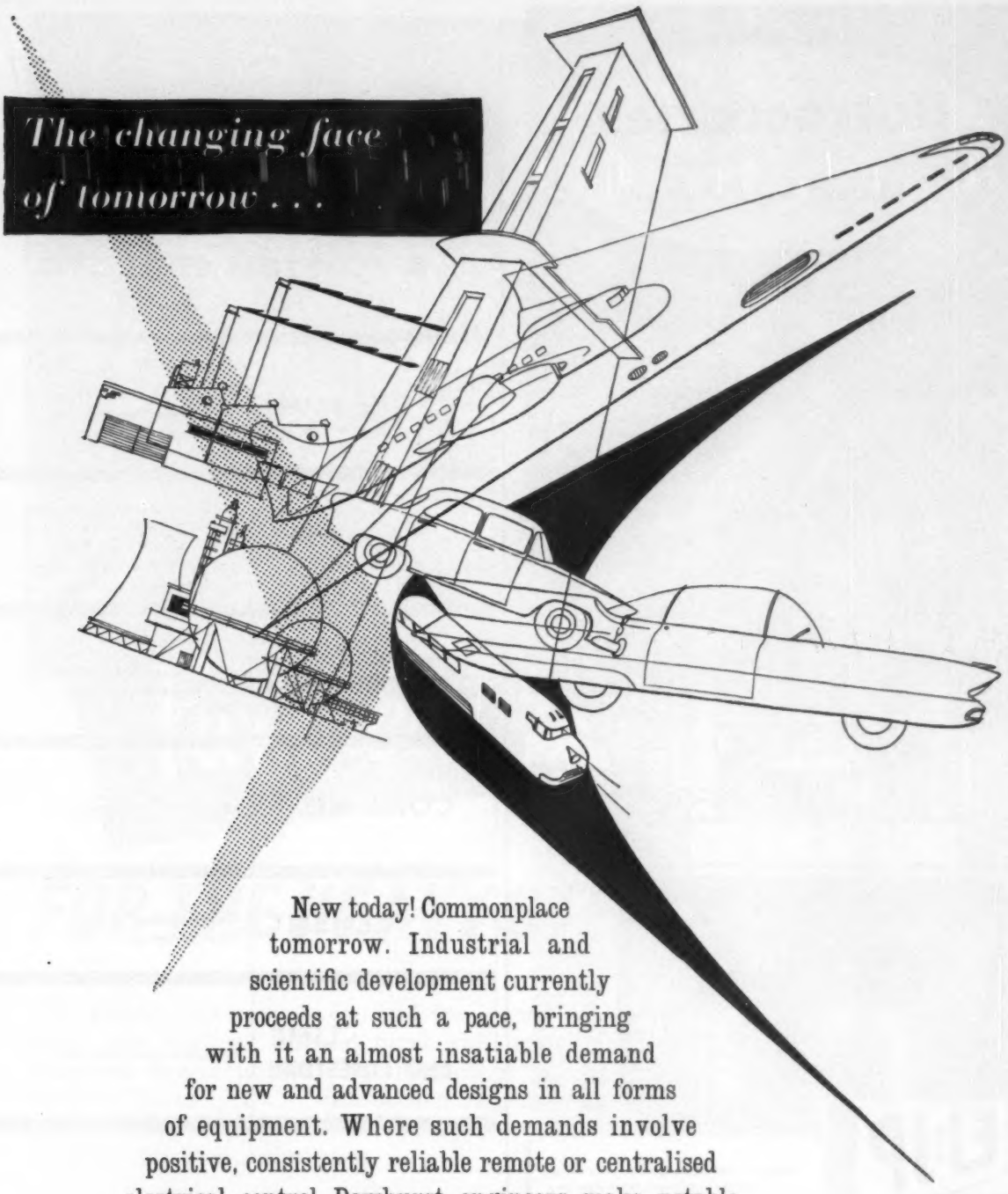

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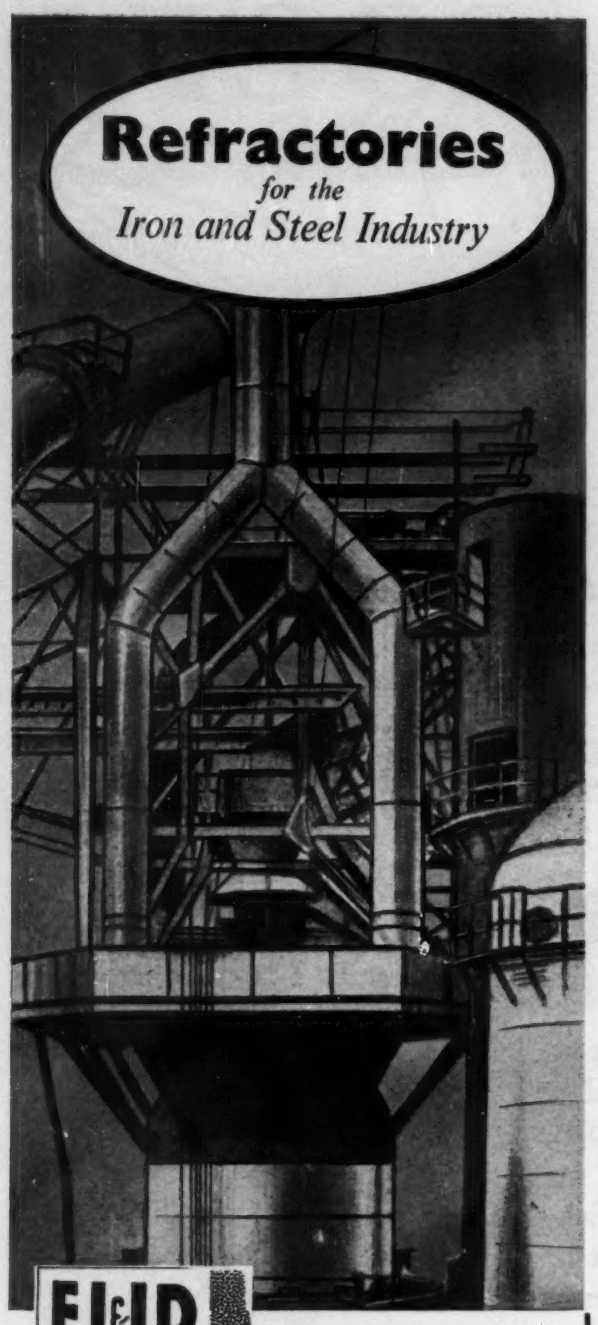

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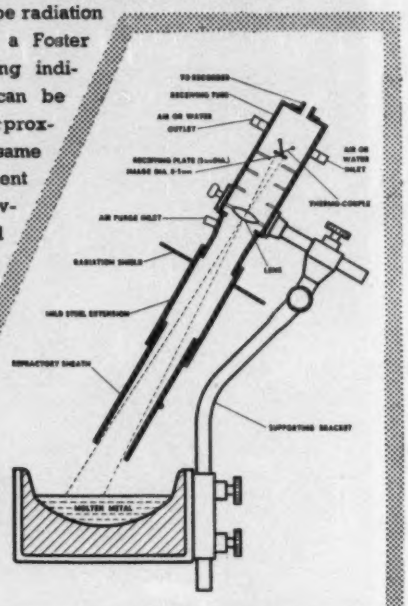

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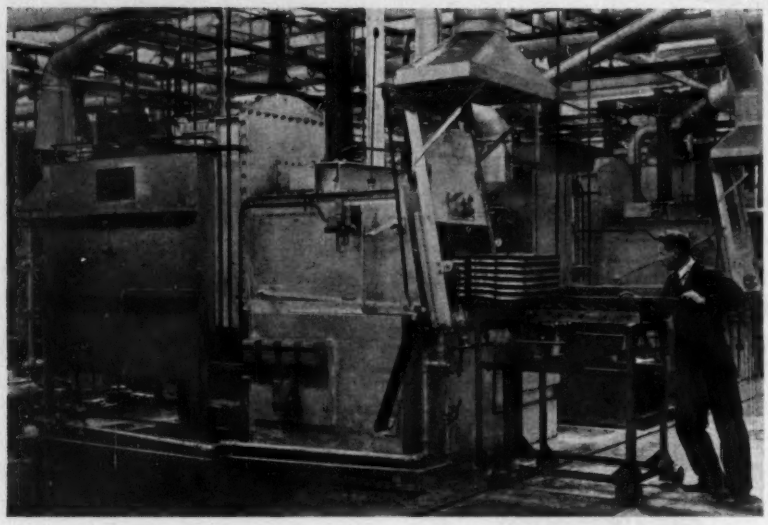

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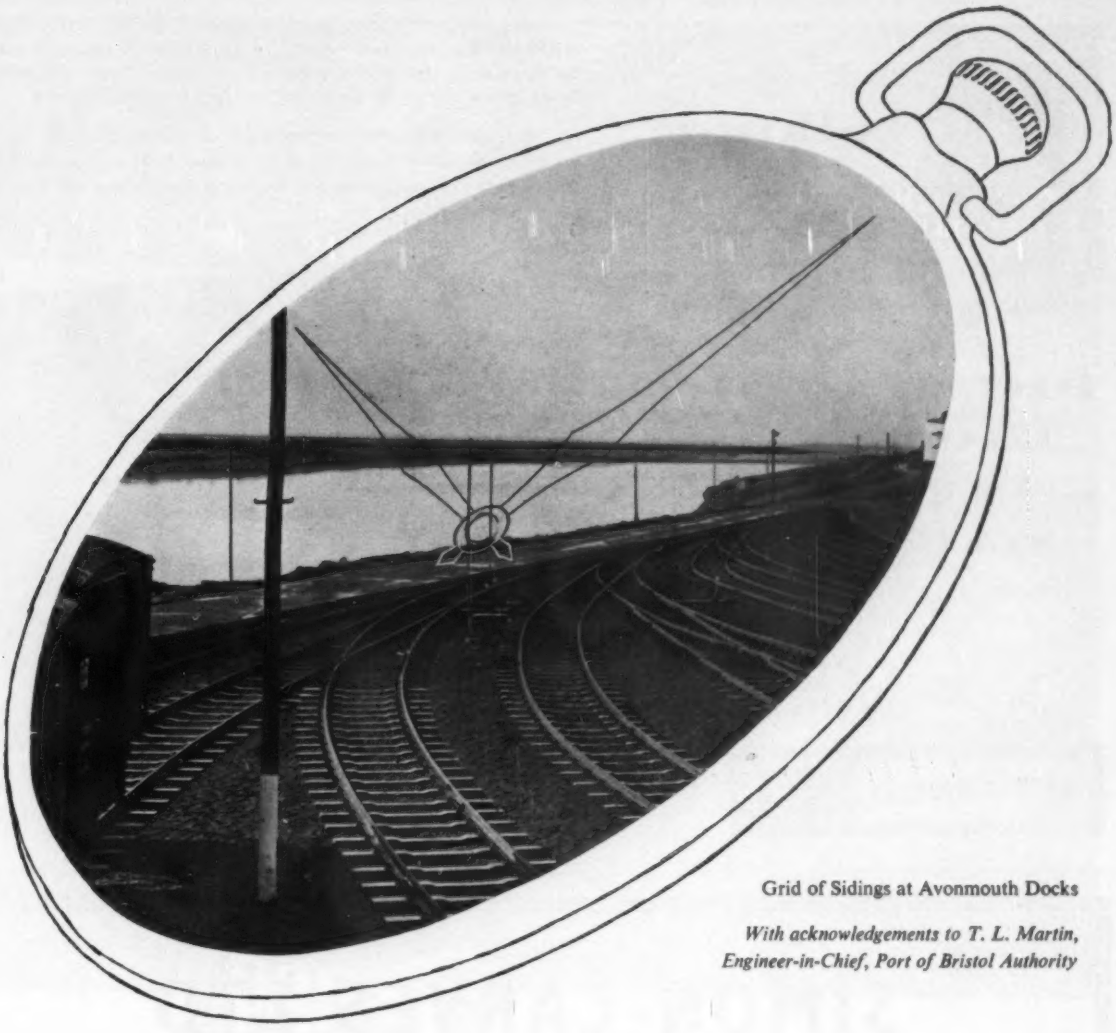

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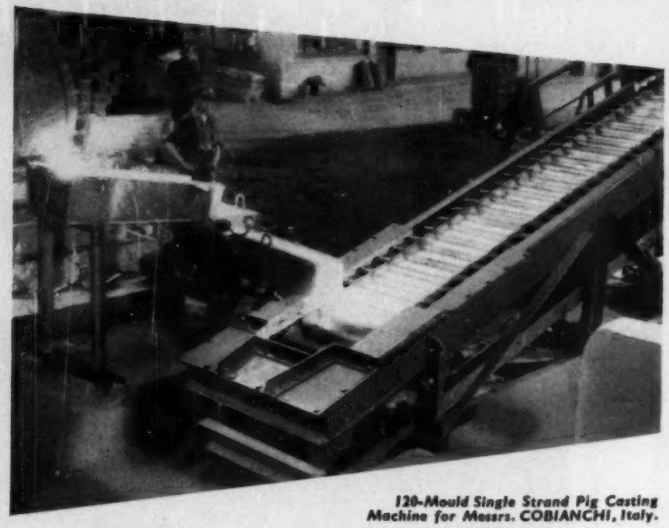

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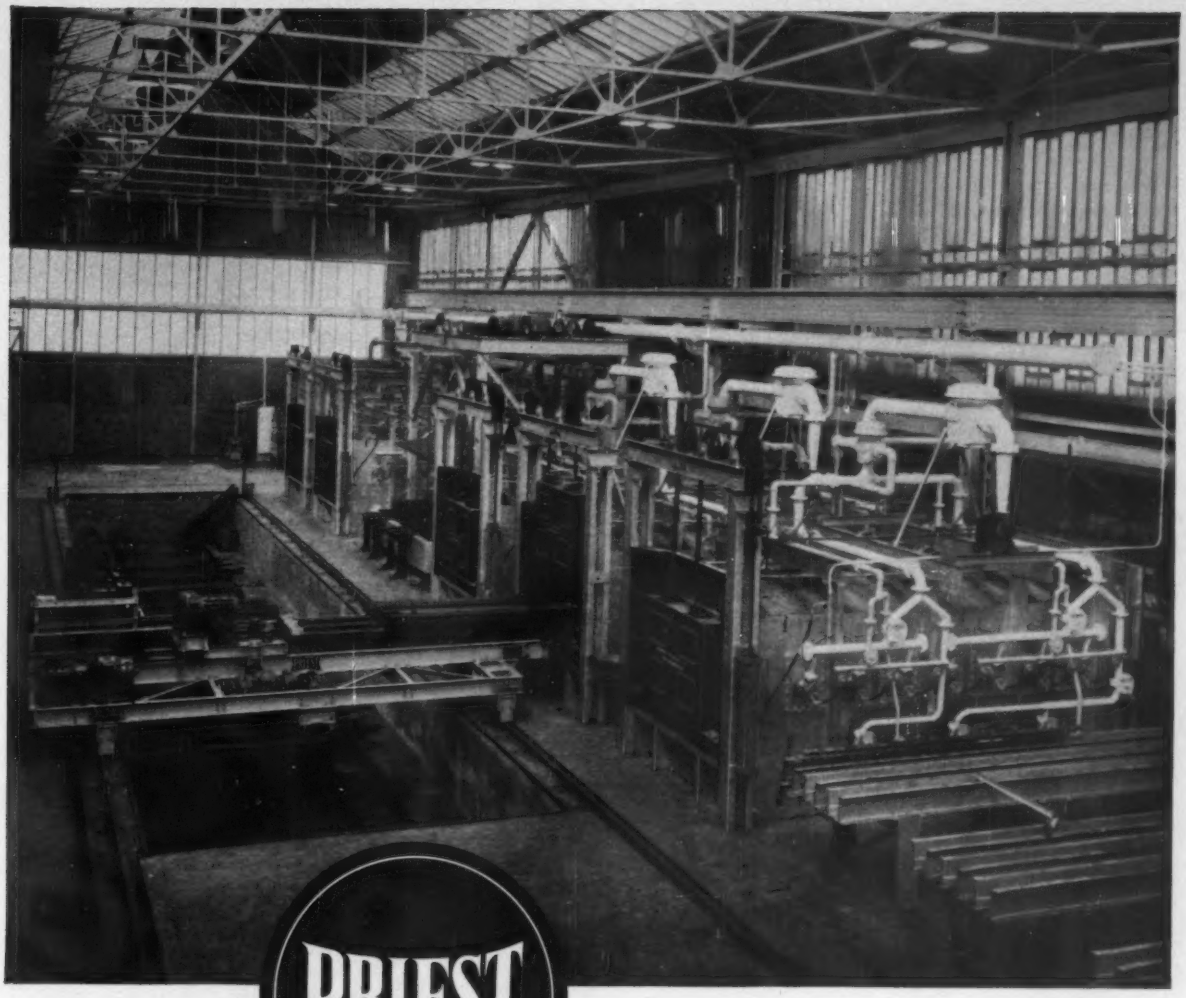

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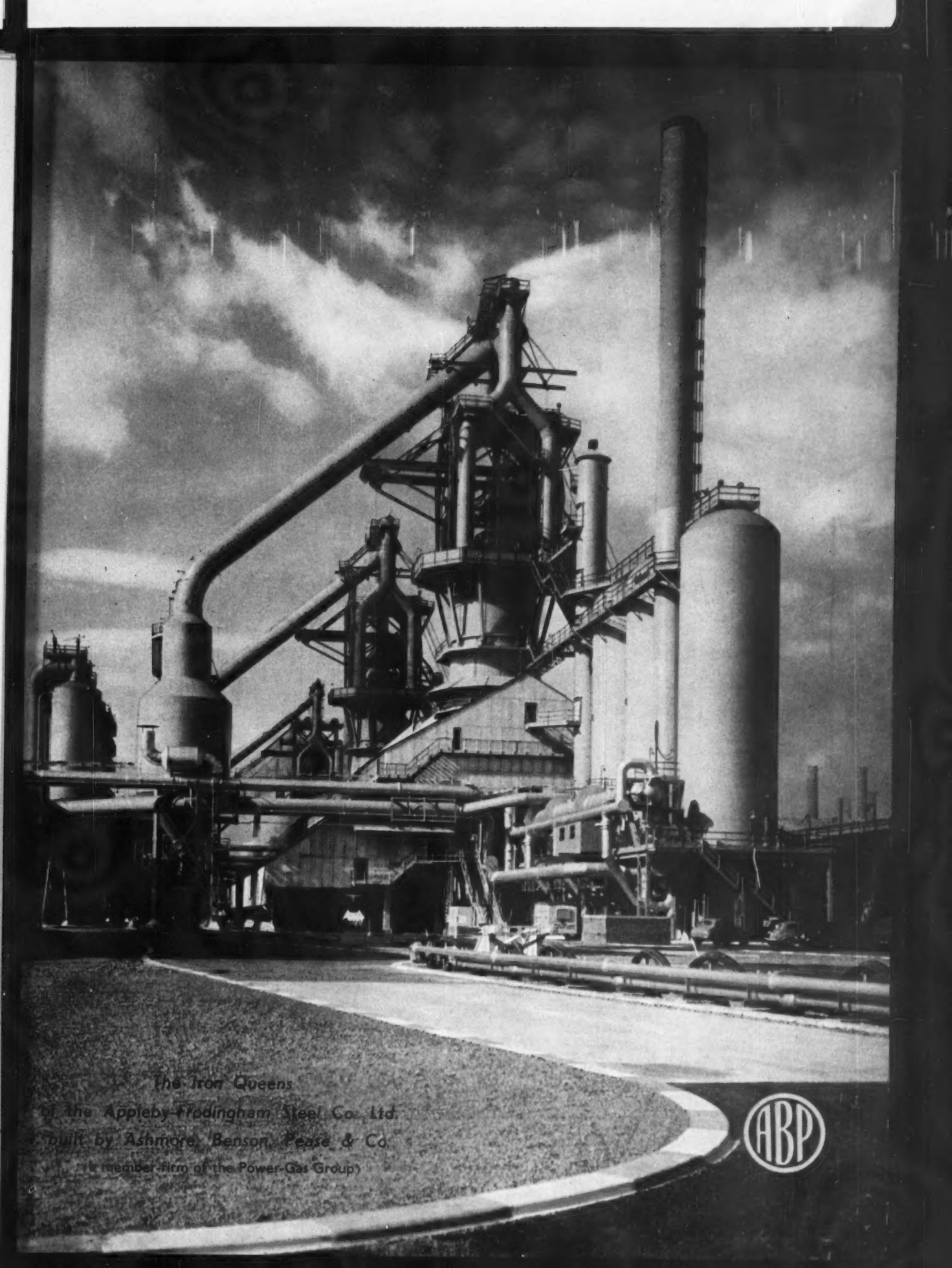
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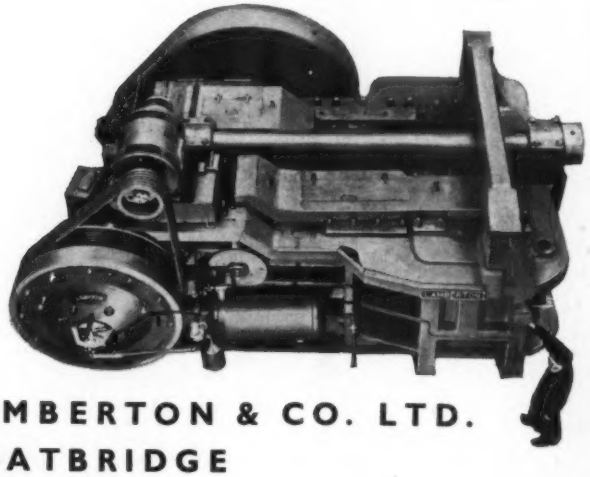

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